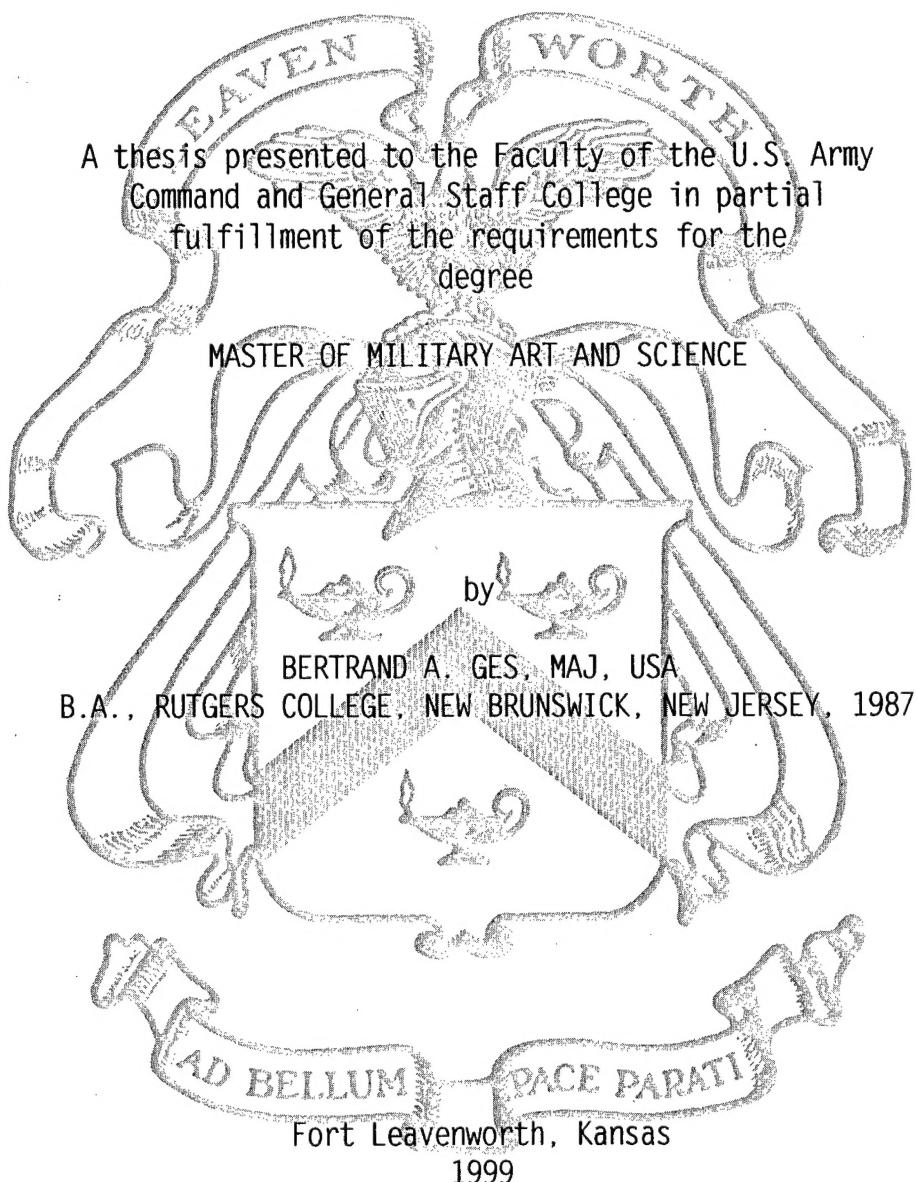


SHOULD THE FUTURE DIRECT SUPPORT WEAPON FOR LIGHT FORCES BE A
105-MILLIMETER HOWITZER?



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105-MILLIMETER HOWITZER?

A thesis presented to the Faculty of the U.S. Army
Command and General Staff College in partial
fulfillment of the requirements for the
degree

MASTER OF MILITARY ART AND SCIENCE

by

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Fort Leavenworth, Kansas
1999

Approved for public release: distribution is unlimited.

MASTER OF MILITARY ART AND SCIENCE

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

SHOULD THE FUTURE DIRECT SUPPORT WEAPON FOR LIGHT FORCES BE A 105-MM HOWITZER? by MAJ Bertrand A. Ges, USA, 100 pages.

This study determines if the 105-mm howitzer should be the future direct support weapon system for light forces from now until the year 2010 and beyond. As the Army prepares to enter the twenty-first century, there is a current capabilities void towards an indirect fire weapon system that supports a mission profile for light forces able to conduct forced entry operations and have airborne and air assault capabilities.

The analysis for this study compares the 105-mm howitzer against a 120-mm mortar and a towed 155-mm howitzer to determine which weapon system is capable of supporting light forces. Lethality, mobility, and survivability are the overall measurements of criteria comparing these three weapon systems against each other. Evaluating each weapon system's capabilities in relation to the criteria of measurements reveal strengths and weaknesses inherent with the characteristics of the indirect firing platform.

Final analysis determines that the 105-mm howitzer should be the future direct support weapon for light forces by consistently ranking within the competing parameters of evaluation. Analysis depicts how the 105-mm howitzer does not rank in the low end for any of the measurements of criteria as compared to the 120-mm mortar and 155-mm howitzer. Comparison data reveals that muzzle loaded mortars have inherent internal and weapon associated characteristics that limit the accuracy of the weapon system to effectively fire on a target.

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ABBREVIATIONS

AGS	Armor Gun System
ATLAS	Advanced Technology Light Artillery System
DCSOPS	Deputy Chief of Staff of Operations and Plans
FDSW	Future Direct Support Weapon
HE	high explosive
HIMARS	High Mobility Artillery Rocket System
HMMWV	high-mobility multipurpose wheeled vehicle
ICM	improved conventional munition
JMEM	Joint Munitions Effectiveness Manual
JTCG/ME	Joint Technical Coordinating Group for Munitions Effectiveness
km	kilometers
LW155	Light Weight 155-mm Howitzer
mm	millimeter
MO	Maximum Ordinate
MSD	minimum safe distances
PeD	probable errors in deflection
PeR	probable errors in range
PM	Product Manager
TAD	target acquisition device
TLE	target location errors

TOF	time of flight
TRADOC	Training and Doctrine Command
UFH	Ultralightweight Field Howitzer
ULW155	Ultralightweight 155-mm Howitzer
USAFAS	U.S. Army Field Artillery School
WAMS	World Artillery and Mortars Systems

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CHAPTER 1

INTRODUCTION

Background

As the United States (U.S.) Army prepares for the twenty-first century with the reorganization and modernization process of Force XXI, linking Army XXI of today with Army After Next from the year 2010 to 2025 (Naylor 1998, 4,5), there is a specificity void towards addressing the type of indirect fire system and concept that supports a mission profile for light forces (Naylor 1998, 4) to conduct forced entry operations and have airborne and air assault capabilities (Macgregor 1997, 77). The field artillery branch has stated that most of Army XXI's materiel programs and enablers are expected to enter the force between 2000 and 2010 (Stricklin 1998, 25). The premier Army XXI delivery system for cannon fires is the 155-millimeter (mm) self-propelled XM2001 Crusader, designed to exploit technology and become the Army's workhorse cannon system for years to come (Baxter 1998b, 3,4). The Crusader is being developed to replace the 155-mm, self-propelled M109A6 Paladin and begins appearing (*Army Weapons And Equipment* [1998], 278) in field artillery battalions in about the year 2006 (Baxter 1998b, 3).

The current direct support howitzer for light and special purpose divisions—possessing airborne and air assault capabilities; is the British designed 105-mm, light towed M119A1 (U.S. Army Field Artillery School [USAFAS] n.d., 3) which replaced the M102 105-mm howitzer. After nearly a decade of development, the 105-mm L118 Light Gun, manufactured by the Royal Ordnance Division of British Aerospace, entered service with the British Army in 1974 (Clancy 1997, 126). Following the British success in the Falkland Islands campaign, the U.S. Army started to look seriously at the battle proven L118, which was the only artillery piece used in the Falklands campaign by the British Army. The L118's superior accuracy in the Falklands and greater range over the American M-102 howitzer (Scales 1994, 212,225) set the premises for U.S. Army testing. After evaluating the L118 for over a year, the decision to purchase an "Americanized" version of the L118 was made in 1986. Except for the first 150 units, American companies would manufacture the M119A1 howitzer under a U.S. license (Clancy 1997, 126). Rock Island Arsenal in Illinois manufactures the howitzer while the Watervliet Arsenal in New York makes the actual 105-mm barrel. The first unit equipped with the M119A1 in 1989 was the 7th Infantry Division of Fort Ord, California. The U.S. Army's key decision of evaluation for choosing the

M119A1 was its ability to airlift an entire division artillery (DIVARTY) within a light division's air transport constraints (Foss 1998, 752).

The Army extended the expected service life for the M119A1 howitzer from 2006 (USAFAFS 1996, 3-1) to 2010 (USAFAFS 1998d). Not until 1995 did the Deputy Chief of Staff of Operations and Plans (DCSOPS) for the Army task for a study titled Legal Mix VIII, which focused on determining the best mix of artillery weapons and munitions to support light forces into the twenty-first century (USAFAFS 1996, 1-1). On 27 November 1997 the U.S. Army Training and Doctrine Command (TRADOC) approved a mission need statement (Herman 1998, 434), defining the requirement for a future direct support weapon system (FDSW) as a lightweight, highly lethal, survivable cannon system for Force XXI and Army After Next light forces. In 1998 the field artillery branch announced plans for the Advanced Technology Light Artillery System (ATLAS) to support light forces, especially those designed for forced-entry units (Baxter 1998b, 3).

Legal Mix studies are a series of DCSOPS studies starting in the 1960s to determine field artillery forces for the future. The purpose of the Legal Mix VIII study was to determine the optimal mix of field artillery systems to best support light forces in three categories:

1. Direct support weapon

2. Divisional general support weapon
3. Reinforcing field artillery brigade with a mix of cannon and rocket battalions

Legal Mix VIII evaluated the 105-mm howitzer, 120-mm mortar, 122-mm howitzer, 155-mm howitzers, and the High Mobility Artillery Rocket System (HIMARS), all against each other. The 105-mm howitzer used for Legal Mix VIII was the M119A1 while the 155-mm howitzer was represented by two types of systems in development titled the Light Weight 155-mm Howitzer (LW155) and the Ultralightweight 155-mm Howitzer (ULW155) (USAFAS 1996, 1-1, 1-2). The LW155 depicted in the Legal Mix VIII study is part of the joint development program between the Army and the United States Marine Corps which has evolved into the XM777 Ultralightweight Field Howitzer (UFH) towed 155-mm howitzer. The UFH is not the ULW155 of the Legal Mix VIII study. The ULW155 evolved into the FDSW and is commonly known now ATLAS (table 1).

The Army and Marine Corps developed the UFH to either augment or replace the M198 155-mm towed howitzer (*Army Weapons And Equipment* [1998], 282). The Marine Corps initially identified the requirements for a UFH prototype in a mission need statement in 1993 and the Army later endorsed it in 1994 (Liles 1998, 375). On 29 September 1995, the

Army and Marine Corps signed a Joint Operational Requirements Document for the actual development of UFH type of howitzer (Ward 1998, 456). Up

Table 1. Legal Mix VIII Weapon Categories

Legal Mix VIII Weapon Category	Current Weapon System
M119A1 (105-mm howitzer)	M119A1 Light Howitzer
M120 (120-mortar)	M120/M121 Battalion Mortar System*
LW155 (155-mm howitzer)	XM777 UFH
ULW155 (155-mm howitzer)	FDSW (or ATLAS)
D-30 (122-mm howitzer)	D-30 howitzer
HIMARS (multiple rocket launcher)	HIMARS

*M120 120-mm mortar is for towed equipment and the M121 120-mm mortar is the carrier-mounted version (Gardner 1998, 442).

until the November 1997 approved mission need statement defining the requirement for a FDSW, which purposely avoids specifying a 105-mm or 155-mm cannon, the response to meet future demands required of light forces to conduct forced entry missions focused on using a 155-mm howitzer. Developing a 155-mm howitzer to support light units has economical and efficiency advantages (Hull 1999), such as converting all howitzer cannons to fire the same 155-mm munition. However, negative

characteristics associated with 155-mm howitzers may impact on the field artillery's ability to directly support today's light forces, specifically, the 82d Airborne Division's contingency mission; and the 101st Airborne Division's (Air Assault) specialized mission capabilities (Steele 1998, 35).

Major General Joseph "Keith" K. Kellogg, Jr., current Assistant DCSOPS of the Army responsible for setting Army priorities and assisting in funding decisions and recommendations on equipping, training and manning the force, voices a concern towards a perception within the Army. Major General Kellogg stated during an interview with the *Fayetteville Observer-Times*, 25 July 1998, that "the Army is not paying enough attention to first-to-fight forces such as the 82nd Airborne Division." Major General Kellogg goes on to say, "There is a schism between the light and heavy forces...(and) the modernization flow and the thinking is going toward the heavier side of the Army." Major General Kellogg further cites the imbalance of funding towards the Crusader as compared to the smaller and lighter 105-mm howitzer as an example. Finally, Major General Kellogg warns that the Army will lose its historic balance of light and heavy forces as well as its status as the vanguard of the U.S. military (Cunningham 1998a, 1,2).

In tomorrow's battlefields, variations of these special units with unique forced entry capabilities, will play a significant role for the Army's light, forced entry, and strike force elements (Kernan 1999, 4).

Problem Statement

The procurement process for the Army is experiencing, and will continue to in the future, severe restrictions in its ability to obtain and implement new weapon systems and concepts. Current and future army decision makers seek out duplicity of capabilities within the Army inventory in order to eliminate redundancy with present and future weapon systems (Newman 1998, 2-3). Ever increasing developments with mortar systems, specifically 120-mm mortars, coupled with the lack of progression in 105-mm howitzers (Mullins 1998) and their suite of munitions (USAFAFS 1998c) may lead to the elimination of our DIVARTYs within our light divisions as the Army plans for future force structures. The 82d Airborne Division's 3-73 Armor's deactivation in July 1997 of the Army's only airborne battalion (Cunningham 1998, 1) best captures the dilemma of eliminating perceived capability redundancies while attempting to maintain adequate combat power.

The 3-73 Armor's deactivation is a result of the Army canceling the acquisition of the XM8 Armor Gun System (AGS) in 1996, for reasons of economy (Macgregor 1997, 80). The AGS was to replace the Sheridan,

M551A1 Armored Reconnaissance Airborne Assault Vehicle which reached its end of service life cycle. Army senior leaders decided to eliminate the funding for the AGS (Cunningham 1998a, 1) and replace the armor capability for the 82d Airborne Division with an Immediate Ready Company consisting of four M1A2 Abrams tanks from the 3d Infantry Division (Mechanized). However, the strategic deployability capabilities between the two weapon systems are significant. The AGS, as did the Sheridan, could enter an area of operation by parachute insertion and immediately provide the 82d Airborne Division with a viable armor asset. The M1A2 tank cannot be inserted by parachute and can only be air landed by C-17 or C-5 aircraft only after the field landing strip has been cleared for aircraft (82d Airborne Division 1998, B-5). Future U.S. Army potential combat losses will ultimately determine the validity of deciding to cancel the AGS and provide the Immediate Ready Company as an alternative (Clancy 1997, 116).

If future Army decision makers are willing to eliminate an armor asset the 82d Airborne Division once readily possessed for its contingency mission (Steele 1998, 35), who will stop the Army from exploring possible alternatives and eliminate the 105-mm howitzer weapon system and not replace it with an adequate alternative?

Research Questions

Should the Future Direct Support Weapon (FDSW) for light forces be a 105-mm howitzer? Currently, the 105-mm howitzer is the field artillery weapon system providing direct support artillery to light and special purpose Army divisions and forces (USAFAS n.d., 3). The answer determines if the 105-mm howitzer has utility for today's and tomorrow's combat forces.

The secondary question answers if 105mm howitzers are better than 120-mm mortars to support light, forced-entry, or strike forces from now until 2010 and beyond? This research chooses the 120-mm mortars, specifically the M120 Battalion Mortar System, because their upgrades in fire control systems (Burke 1998, 261) and ammunition (Product Manager [PM] Mortars 1999) are comparable or greater than 105-mm howitzers.

Finally, the thesis answers if 105-mm or 155-mm towed howitzers are better suited to support light, forced-entry, or strike forces from now until 2010 and beyond?

The criteria of measurement used to compare these weapon systems against each other are: lethality, mobility, and survivability. The results from these measurements of criteria will determine if 105-mm howitzers are better suited than 120-mm mortars or 155-mm howitzers to

support today's light, forced-entry, or strike forces from now until 2010 and beyond in combat operations.

Significance

Light Forces need fire support that is responsive, highly mobile, lethal, and able to engage the threat sufficiently forward of the front line of troops (FLOT) to disrupt, fix, disorganize, and suppress the threat force before the initiation of the close-in direct fire fight. They also need fire support that is quick, accurate, and survivable. Finally, Light Forces need a direct support weapon system that can provide a high volume of fire when necessary, and employ a suite of munitions that will counter the spectrum of threat targets they expect to encounter. The success of early entry operations depends on the rapid introduction of highly lethal attack systems. Employment of towed cannon systems to provide this support is constrained by limited strategic and tactical lift. It is essential that each combat weapon system maximize firepower while limiting size, weight, and ability to be quickly employed once on the ground (USAFAS n.d., 2).

A field system review of M119A1 howitzer users and maintainers provided feedback in October 1993 identifying inadequacies concerning tactical mobility and operational effectiveness (Mullins 1998). The improvements required for the M119A1 were necessary to have it last through the anticipated service life cycle. The lack of technological advancements for the M119A1 howitzer and its suite of munitions, as compared to the capabilities of current and future 155mm howitzers and all mortar systems, makes the M119A1 insufficient to support light forces in any type of major regional conflict (DCSOPS 1997, 9).

Key military leaders first identified a strategic airlift capacity shortfall in the late 1970s for the U.S. Air Force. Beginning in 1981, President Ronald W. Reagan and his administration increased defense spending to improve the strategic airlift capacity. As a result, the introduction of the McDonnell Douglas C-17A Globemaster III aircraft to replace the aging fleet of Lockheed C-141 and C-5 long-range airlifters (Clancy 1997, 192, 183, 182) is currently adequate, but with no major increase in the amount of strategic airlift expected, available strategic airlift capacity will always remain constrained (USAFAS n.d., 1) from now until Army After Next.

The 82d Airborne Division's planned invasion for Haiti in 1994 only had a four-gun battery of M119A1 howitzers rigged for the parachute assault into Porte-au-Prince International Airport with the mission to provide all weather, around-the-clock fire support. The limited suite of munitions available for the M119A1 constrained its usefulness in the operation. The other artillery weapon system available within the XVIII Airborne Corps for employment in the operation were the 155-mm towed M198 howitzers. Senior leaders had to choose from either a 33-pound explosive filled projectile fired by a highly mobile and deployable M119A1, or a 95-pound projectile fired by a M198 that was considered too large and too heavy to maneuver on the ground. Ultimately, these senior

Leaders were choosing between two extremely different explosive effects. Another factor was that only the M198 howitzers could achieve surface artillery precision fire with the M712 Copperhead cannon-launched guided projectile. However, limiting collateral damage with the M712 Copperhead would still be difficult because of the explosive weight of the round (Gottardi 1999).

Given those dilemmas confronting senior leaders during the planning of the Haiti invasion for what type of artillery system to deploy, it would be tempting in the future to decide to not deploy any howitzers for a contingency mission and have the infantry battalion task forces rely solely on their own mortar systems. With the continued improvements in mortar fire control systems and in ammunition (Burke 1998, 261,265,266,267,268), those types of decisions to forego howitzers become very viable. Additionally, the maneuver task force commander's decision to choose mortar systems over M119A1 howitzers is made easier when looking at the benefit of saving sortie lift aircraft. Eliminating howitzer platforms in lieu of mortars allows the maneuver task force commander greater capability to bring other critical items, to include additional personnel, into the area of operation by strategic air lift capabilities (Lindsey 1995, 3). Given the same Haiti scenario with competing requirements for availability of aircraft based on weight of

cargo and lethality, it becomes challenging to include howitzers for initial deployment, especially howitzers exceeding current total weight to include ammunition, basic issue items, and crew of the M119A1. These factors become compounded as the Air Force transitions its fleet of strategic airlift capacity from C-141s to C-17s and maintains their C-5 and C-130 aircraft (Cummins 1997, 3,4). The final analysis must consider the assets based on significantly enhancing a unit's combat effectiveness (Gottardi 1999).

Underlying Assumptions

Ammunition and Weapon Systems

The ammunition and weapon systems used for the measurements of criteria comparing weapons systems are those active munitions and indirect firing platforms currently acknowledged by the Firing Tables Branch of the Army Research, Development, and Engineering Center (ARDEC) and provided to the Army Material Systems Analysis Activity (AMSAA) for accuracy modeling as of 23 February 1999.

The ammunition assumption precludes using various forms of competing future estimates to include range, lethality, and weight. Additionally, only standard high explosive (HE) munitions are used in comparisons and does not include improved conventional munitions (ICM), rocket assisted projectiles or propellant enhanced projectiles. This is

to eliminate discrepancies between varying suites of ammunitions, specifically the 120-mm mortar not currently having a range enhanced or an improved conventional munition (ICM). PM Mortars is developing a XM984 120-mm extended range dual purpose ICM mortar cartridge which will give it greater range and lethality (PM Mortars 1999) as the 105-mm and 155-mm howitzers currently achieve with their with their ICM rounds (figure 1). The intent of this effects modeling is to determine a true measure of a weapon's ability to hit a target.

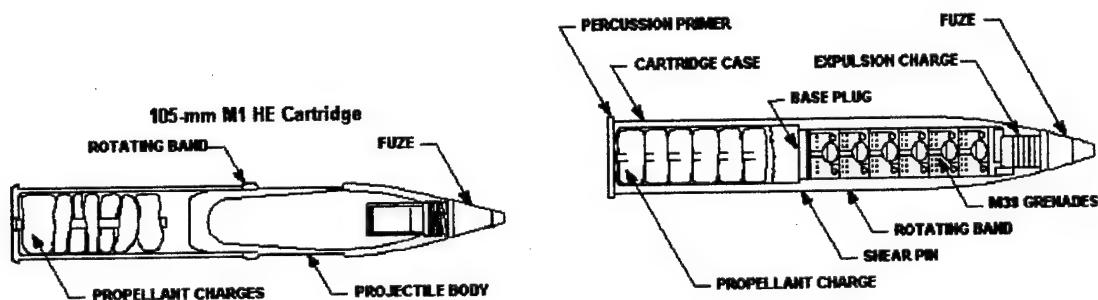


Figure 1. Standard HE (left) and ICM rounds (right). The HE round's projectile body is a bursting charge filled with either trinitrotoluene (TNT) or composition B. The ICM round's body assembly contains grenades (ST 6-50-19 1989, 12-11, 12-13).

The weapon system assumption precludes concepts such as the Marine Corps' 120-mm Dragon Fire Box Mortar System, a naval 5-inch (127-mm) cannon on a D-30 howitzer chassis (Briggs 1999), and the expected capabilities of the XM777 UFH 155-mm howitzer until final verification

of data testing is done. Many of the inherent mortar characteristics in the conceptual Dragon Fire are the same with the 120-mm M120 Battalion Mortar System.

Financial Costs

Costs to improve or develop a 105-mm howitzer, 155-mm howitzer, or 120-mm mortar, and their associated suites of ammunition, to become the FDSW are all relative to each other.

Modeling

The statistical model to obtain weapons effects as part of the lethality measurement of criteria is the Joint Munitions Effectiveness Manual (JMEM) Surface-to-Surface World Artillery and Mortars Systems (WAMS) CD-ROM. This data is SECRET-NOFORN (no foreign national). The research techniques of this thesis declassify the data results through a combination of transforming the information into ratios and using an unclassified version of WAMS, all while monitoring consistency in data results. The measures of effectiveness used by JMEM/WAMS are expected fraction of casualties and expected fractional damage. JMEM/WAMS uses ARTQUICK, the Simplified Artillery Effectiveness Model. ARTQUICK is a personal computer effectiveness program to determine the values for expected fraction of casualties and fractional damage. ARTQUICK estimates effectiveness of weapon systems using unguided HE and ICM

munitions against targets. Estimates to achieve desired damage/casualty levels consider posture sequencing. For artillery systems ARTQUICK has a 95 percent assurance that results are within 5 percent of expected fraction of casualties and fractional damage values, and 10 percent of expected fraction of casualties and fractional damage values for mortar systems.

JMEMs were first published in 1964 to ensure scientific consistency and objectivity for the Department of Defense. Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) publishes the JMEMs under the auspices of:

1. Commanding General, Army Materiel Command
2. Deputy Chief of Naval Operations (Resources, Warfare Requirements and Assessments)
3. Commander, Air Force Materiel Command (JTCG/ME 1997).

Target Description Profile

The target source is a willing, credible and able enemy. The target category is personnel operating a machine gun position in an open environment with a target size of a 50 meter radius, the most consistent, immediate threat that a light force battalion unit, or greater, can expect to encounter while conducting combat operations (Soby 1999; & TRADOC Analysis Center 1995). Target size of a 50 meter

radius is the lowest JMEM/WAMS default value to replicate target threat. The target location errors (TLE) and circular error probable are zero meters. Target criteria of open environment and values of zero for TLE and circular error probable are the best conditions for all weapons systems to achieve greatest effects.

Effects of Fires for Desired Damage

The Army defines the effects of fires for fire support assets as destruction, neutralization, and suppression. Destruction puts a target out of action permanently by achieving 30 percent casualties or materiel damage. Neutralization puts a target out of action temporarily by achieving 10 percent or more casualties or damage. Suppression limits the ability of enemy personnel in the target area to perform their missions (FM 6-20-20 1991, 1-2), and last as long as the fires continue (Koba 1997, 9), and is therefore a function of time.

The JMEM/WAMS version 1.0 CD-ROM requires a desired damage value to obtain data comparing weapons systems. The effects for fire support assets conducting suppression missions does not have a percentage associated with it, as does destruction and neutralization. Therefore, 5 percent is the value chosen for effects modeling when using the JMEM/WAMS version 1.0 CD-ROM. Fire support weapon systems firing either suppression or immediate suppression missions allow the maneuver force

to get within range of the enemy direct fire weapon systems (Di Ruzza 47, 1999). The volume of suppressive fires from fire support assets possess lethality resulting in an amount of some quantifiable degradation on enemy capabilities. The 5 percent value captures those degraded effects. Finally, choosing a value of 5 percent takes into consideration comments on effects by Lieutenant General William F. Kernan, Commanding General, XVIII Airborne Corps, in an interview with the *Field Artillery Journal* (January-February 1999):

The limitation on our strategic airframes coming into theater restricts the number of howitzers and amount of ammunition we can bring in. Ideally, we want to destroy the enemy, but it takes a tremendous amount of ammunition to fire a destruction mission. In a forced-entry mission, we deploy into the close fight. That means our fires need to suppress the enemy as rapidly as possible to prevent him from engaging us with his direct and indirect fire systems, allowing our infantry to secure the airfield, port or whatever.

Definitions

Howitzer versus Mortar versus Rifle

Range, muzzle velocity, trajectory, and caliber length are the characteristics identifying the differences between a howitzer, a mortar, and a rifle (table 2 and figure 2).

Table 2. Howitzer versus Mortar versus Rifle

Type	Range	Muzzle Velocity	Trajectory	Caliber Length
Howitzer	Medium	Medium	Medium*	20 to 30*
Mortar	Short	Low	High	10 to 20
Rifle	Long	High	Flat	Over 30

*Trajectory is either low or high. Caliber length can exceed 30 calibers if the high angle fire zoning solution permits range overlap between charges (Department of Defense 1998, 178).

(Table information from Student Text [ST] 6-50-19 1989, 2-17)

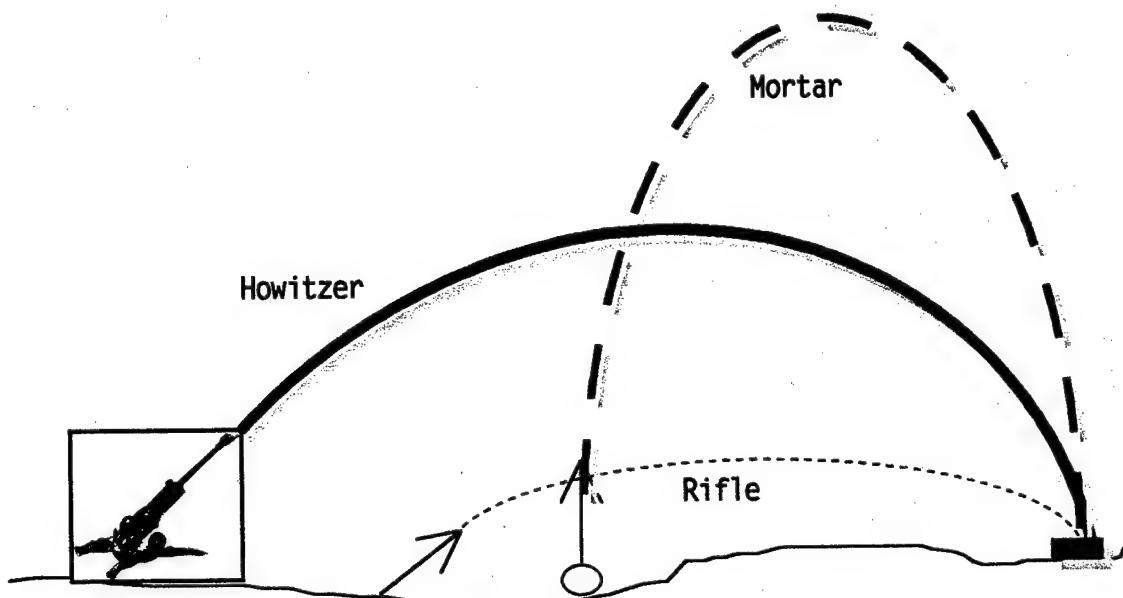


Figure 2. Howitzer versus Mortar versus Rifle (ST 6-50-19 1989, 2-17).

Screening criteria

The U.S. military must have an existing suite of munitions for weapon type comparison. This initial screening eliminates the Russian-made 122-mm D30 howitzer, which first became operational in the Soviet Army in the 1960s (Briggs et al. 1997, 54).

Measurements of criteria

The criteria to compare the 105-mm howitzer, 120-mm mortar and the 155-mm howitzer against each other are:

Lethality

Components of lethality are weapons effects data from the JMEM/WAMS CD-ROM and the inherent characteristics associated with the weapon system to achieve the five elements for accurate predicted fire.

Survivability

The ability of the indirect fire weapon system to protect itself from an imminent threat and not get acquired by enemy assets.

Survivability also includes safety aspects for weapon system crew members and friendly, maneuvering soldier's exposure to risk from indirect fires in relation to minimum safe distances (MSD).

Mobility

Components of mobility are strategic and tactical. Strategic mobility is the ability to transport the indirect fire weapon system by

strategic lift assets of air or sea into an area of operation. Tactical mobility is the ability of the indirect fire weapon system to tactically move by ground or air in an area of operation.

Five requirements for accurate predicted fire

To achieve accurate first-round fire for effect on a target, an indirect fire unit must compensate for nonstandard conditions as completely as time and the tactical situation permits. Achieving the five requirements allows the firing unit to deliver accurate and timely fires in support of the maneuver element. The five requirements are:

Target location and size. Consists of accurate and timely detection, identification, disposition, location, and size of the target.

Firing unit location. Consists of accurate location, altitude, azimuth of lay and precise location of an individual firing weapon system.

Ammunition and weapon information. Consists of accounting for specific ammunition information to include weight, propellant temperature, and associated fuze; the muzzle velocities for firing speed of projectiles; and cant of the weapon.

Meteorological information. Consists of various effects of weather on the ammunition while in flight to include wind direction and speed, air density, and temperature.

Computational Procedures. Consists of automated and manual techniques to determine the most accurate firing data (FM 6-40 1996, 1-3, 1-4).

Light forces

Consists of light infantry that have strategic and operational capabilities such as light infantry, airborne infantry, and air assault infantry (Kinnison 1998, 277). Light forces can operate effectively in most terrain and weather, and can be rapidly deployed because of their austere design and unique modes of entry into battle (FM 100-5 1993, 2-22). The mission of light infantry forces is to close with the enemy by means of fire and maneuver to defeat or capture the enemy or to repel their assault by fire in close combat, and counterattack (Kinnison 1998, 280).

Field artillery units that support these types of light forces are called light field artillery forces (USAFAS n.d., 1) or light artillery (Byrne 1998, 48).

Strike Force

General Dennis J. Reimer, Army Chief of Staff defines the strike force as a unit of approximately 5,000 soldiers, having the ability to deploy, almost immediately, a lethal modular force, tailored to operational requirements, and able to sustain itself and survive until mission completion or follow on forces arrive. Strike Force is part of a rapidly deployable, flexible and adaptive early entry force. It is intended to complement current light and heavy force capabilities. The Army creates the first strike force within the year at Fort Polk with the 2d Armored Cavalry Regiment (ACR) as the unit testing equipment, doctrine, techniques, tactics and procedures. The strike force expects to be operational by 2003 (U.S. Army Public Affair 1999).

Brigadier General Daniel R. Zanini, deputy chief of staff for combat developments, TRADOC, describes a strike force as a bridging force between the Army's six heavy divisions and four light divisions. Brigadier General Zanini further cites that the purpose of a strike force is to eliminate the 1991 vulnerability that the 82d Airborne Division initially had in Saudi Arabia until elements of the 24th Infantry Division arrived on the ground (*Strike force maybe key to future Army [1998]*, 21).

Discussions have explored the notion that the strike force could also possess an airborne-air assault mission profile (Macgregor 1997, 7) and with modifications to the existing 82d Airborne and 101st Airborne (Air Assault) Divisions, there would no requirement to resource a third type of force (Kernan 1999, 4).

Limitations

Modeling for direct fire capability, range entries, and status of

XM777 UFH

The JMEM/WAMS version 1.0 CD-ROM, or any other JTAC/ME product, does not have the capability to determine direct fire weapon effects for any type of 105-mm howitzer, 155-mm howitzer, or 120-mm mortar.

Additionally, consistency of entry values for range of firing piece to target do not exist for each weapon system, limiting entries from 100 meter to one kilometer increments. However, achieving common ranges for comparison occurs by rounding to a common range for all weapon systems.

The XM777 UFH technical firing data verification is still on going. Initial analysis has the XM777 matching aiming data very closely with the M198. The only initial differences will probably occur in muzzle velocity of a few meters per second at the top zones of charges (Matts 1999). Therefore, the M198 surrogates the XM777 UFH for JMEM/WAMS modeling.

Secret Classification of certain data

Keeping this thesis as an unclassified document precludes certain data from being revealed in its truest form. The actual results of obtaining weapons effects as part of the lethality measurement of criteria from using JMEM/WAMS is SECRET/NOFORN. Comparing specific number of rounds to achieve specific percentages of desired levels of damage would give the best representation of weapon systems against each other. However, normalizing actual JMEM/WAMS data by converting information into ratios and verifying trends with an unclassified version of WAMS does not diminish the purpose of comparing weapons systems against each other.

The actual Legal Mix VIII study is a classified document. DSCOPS and TRADOC (Gardner 1999) denied access to view the classified version of Legal Mix VIII. However, access to the unclassified version of Legal Mix VIII to include the executive summary does not diminish the purpose of determining comparisons of weapons systems against each other.

Delimitations

Data collection cut-off point

The data collection cut-off point is 24 February 1999 with the assumption that all data and information collected up to that date is

current and valid. The References contain four items of data collected after 24 February 1999 because verification of information occurred.

Cost Estimates

The Legal Mix VIII study states that cost data for future improvements or new acquisitions of equipment are difficult to address (USAFAS 1996, 4-18). Finally, cost estimate variances from combat development directorates, PMs, and TRADOC systems managers (TSM) are not consistent (Grigsby 1999).

HIMARS, Multiple Launcher Rocket System (MLRS), and Enhanced Fiber-Optic Guided Missile (EFOG-M)

The Department of Defense defines direct support artillery as artillery assets with a primary task to provide fires requested by the supported unit (Department of Defense 1998, 132). HIMARS, Multiple Launcher Rocket System (MLRS), and Enhanced Fiber-Optic Guided Missile (EFOG-M) would normally not fill a direct support role for light forces at brigade and battalion level.

Operational Requirements Data

Operational requirements for a light howitzer to support light forces only reviews as far back as the data to field the M102 105-mm howitzer in the 1960s.

CHAPTER 2

LITERATURE REVIEW

Historical Perspective

The Legal Mix VIII study of 1995 is the official Army genesis for what has evolved into the requirements for a FDSW for light forces.

Prior to Legal Mix VIII, Legal Mix V of 1977 and Legal Mix VII of 1991 addressed only side issues pertaining to the field artillery supporting light forces. The results and recommendations from Legal Mix V and VII were the starting points for Legal Mix VIII (USAFAS 1996, 1-1).

Background on the development of the M102 105-mm howitzer to replace the World War II vintage M101A1 105-mm howitzer (*Army Weapons And Equipment* [1998] 279) better explains why a DCSOPS tasking for a Legal Mix study focusing on the requirements of light forces finally occurs in 1995. The Army identified the requirement for a M102 in 1960. In December 1965, the Army mass produced the first M102 howitzers and a month later put them in South Vietnam for combat (Foss 1998, 752). The Army advertised the M102 as a lightweight towed howitzer with a very low silhouette when in the firing position. The M102 possessed several options of employment ideal for light forces:

1. Air lifting by CH-47 or CH-54 helicopters
2. Towing by M561 Gama Goat

3. Dropping it by parachute (ST 6-50-19 1989, 4-1)

The M102's weight of approximately 3,300 pounds (*Army Weapons And Equipment* [1998], 279) versus the 4,980 pounds for the M101A1 (ST 6-50-19 1989, 3-1) and the M102's ability to rapidly traverse 360 degrees to engage targets in other sectors (Foss 1998, 752), met the Army's requirements for light forces in the 1960s and 1970s. In the 1980s, the Army's "off the shelf" buy of the 4,100 pound stripped M119A1 (TM 9-1015-252-10 1992, 1-5) from the British was the solution to field a next generation light howitzer without incurring major developmental costs (Clancy 1997, 126).

After the fielding of the M119A1 in 1989, the Army conducted a fielded system review in October 1993 of the howitzer's users and maintainers. The results of the review was a Light Artillery System Improvement Plan containing at least 16 upgrades. The goal of the Light Artillery System Improvement Plan for the M119A1 was to lower operating costs and improve tactical mobility and operational effectiveness (Mullins 1998).

Understanding the Problem

In a 1999 interview with Charles S. Soby, U.S. Army, Colonel, Field Artillery; Director, Center for Army Tactics, U.S. Army Command and General Staff College, he explained, "The primary question is, 'What

does the maneuver commander need? What does he expect his fire support system to do?' Then you evaluate your alternatives...based on what he needs us to do."

The Legal Mix VIII study's conclusion that the FDSW for light forces be a ultralightweight 155-mm howitzer immediately sparked a debate. As a result, numerous studies, experiments (actual field testing and computer modeling), articles, and with the advent of electronic mail, open debate, have contributed immensely towards determining the final solution for the best indirect fire weapon system to support light forces from now until 2010 and beyond. For the most part, the U.S. Army Field Artillery School (USAFAS), which encompasses the field artillery's directorate, combat development (DCD), initially advocated the lethality effects of a 155-mm FDSW for light forces as concluded in the Legal Mix VIII study. However, since 1998, USAFAS has researched the possibilities for a dual caliber weapon system to satisfy the full spectrum of needs for lethality, while maintaining a focus towards a most demanding, threatening environment (Grigsby 1998a).

To answer Colonel Soby's questions, the *Field Artillery Journal's* interview, January-February 1999, with Lieutenant General Kernan, Commanding General, XVIII Airborne Corps, specifically defines the requirements for not only the current XVIII Airborne Corps force

structure, but also for the composition of the Army's future strike force. Additionally, Lieutenant General Kernan touches upon the suppression versus lethality debate encountered during the early stages of an austere light forces' environment. Colonel Kinnison of TRADOC systems managers (TSM) Soldier, takes Lieutenant General Kernan's definition of light maneuver requirements one step further by defining the dismounted, light infantry concept and force conditions for the year 2010. Finally, a TRADOC Analysis Center (TRAC) study defines what type of target or threat an Army or Marine Corps light force element may encounter in combat.

From the Legal Mix VIII study to the 1998 year end report offered by the Chief of Field Artillery, intermingled with various studies, reports, and recommendation and proposals from the XVIII Airborne Corps Artillery, there is a consistent consensus towards defining the operational requirements for a FDSW for light forces. The field artillery branch alone has gone from the former Assistant Commandant of the Field Artillery School, who also oversees the directorate, combat development (DCD) for the Field Artillery branch, writing an article in the May-June 1998 *Field Artillery Journal* titled "Fires: The Cutting Edge for the 21st Century" that contains no mention of FDSW requirements for light forces, to the Chief of Field Artillery's "From the Firebase"

column, September-October 1998, defining ATLAS and then having the entire *Field Artillery Journal*'s January-February 1999 issue dedicated towards lightfighter fires, and providing Lieutenant General Kernan a forum to specify needs unique to the XVIII Airborne Corps.

Collectively, as a branch of the military, the Marine Corps continues to explore many ways of developing and fielding an indirect fire system to support light forces in an austere environment, to include testing the D-30 122-mm howitzer (Briggs 1999) and the unmanned 120-mm box mortar system Dragon Fire concept. Marine Corps Lieutenant Colonel Forrest R. Lindsey's 22 March 1995 article heavily criticizes the Marine Corps' efforts for continually developing a lightweight 155-mm howitzer and focusing on expanding the role of mortars, vice exploring a potential 120-mm to 127-mm howitzer alternative.

Ironically, retired, Lieutenant Colonel Lindsey's July 1998 *Marine Corps Gazette* article touts the many great advantages of current Marine Corps fire support assets, primarily the M777 155-mm lightweight howitzer (known in the Army as the UFH 155), the 120-mm mortar turreted light armored vehicle (LAV), and the enormous potential for the Dragon Fire 120-mm autonomous mortar (Lindsey 1998, 19).

Marine Corps Lieutenant Colonel Robert W. Strahan's July 1998 *Marine Corps Gazette* article explores how the Marine Corps artillery

procurement process is not consistent with Marine Corps doctrine.

Colonel Strahan recommendation is based on a thorough analysis comparing six indirect fire systems to include both the M198 and XM777 UFH, the M119A1, and the 120-mm armored mortar system (AMS). Certain rankings for his measures of effectiveness are debatable (Strahan 1998).

As the debate continues to determine if the FDSW should have a 105-mm cannon or a 155-mm cannon, senior Army leaders cannot overlook the extensive strides made in mortar development. While no one is specifically advocating that 120-mm mortars replace 105-mm howitzers, Tom Clancy writes in his 1997 book "Airborne: A Guided Tour of an Airborne Task Force" that the future utility of 105-mm howitzers in the U.S. Army is coming to an end. There is a belief that if the Army adopts the 155-mm cannon for the FDSW, the void created in the close indirect fires fight gets assumed by mortars (USAFAS 1996, 3-1; and Soby 1999).

Some see the on-going debate of whether the FDSW is either a 105-mm or 155-mm howitzer as a smaller version of the grander heavy versus light debate within the Army. Major General Robert H. Scales Jr., current Commandant of the U.S. Army War College, describes in "Certain Victory: The U.S. Army in the Gulf War," that the 82d Airborne Division

as isolated and immobile once on the ground, and in open desert warfare, ill-suited against mobile armored forces (Scales 1993, 128).

This type of criticism of light forces and specifically the 82d Airborne Division, falls right into what Major General Kellogg and others have stated as the growing rift in the Army of the heavy versus light communities. In another interview with the *Fayetteville Observer-Times*, 30 July 1998, Major General Kellogg states that there was some animus between General Schwarzkopf, Commander in Chief, Central Command (CENTCOM), and members of the airborne community, resulting with Central Command (CENTCOM) not fully utilizing the 82d Airborne Division to its maximum potential prior to and during the ground war (Cunningham 1998b, 5E). Major General Kellogg's concern of in-fighting can ultimately lead to the Army losing its exclusivity of having light forces conducting forced-entry missions to the Marine Corps.

Colonel Scott Macgregor's controversial "Breaking the Phalanx: New Design for Landpower in the 21st Century," offers a solution to this heavy versus light debate by proposing a complete overhaul of how our forces are currently organized. His "Breaking the Phalanx" proposes that current Army divisions transform into Joint Task Force-Based Army's comprising of four types of combat groups having approximately 4,000 to

5,000 soldiers each. The four proposed combat groups are:

1. Airborne and Air Assault
2. Light Reconnaissance Strike Group
3. Heavy Reconnaissance Strike Group
4. Heavy Combat

Colonel Macgregor has either the towed 155-mm howitzer or 120-mm mortar as the indirect fire weapon system supporting the Airborne and Air Assault Combat Group and the Light Reconnaissance Strike Group.

Colonel Macgregor also includes the AGS with the Light Reconnaissance Strike Group as an important component for the organization (Macgregor 1997, 77, 79, 80).

Sean Naylor of the Army Times writes how the Army plans to implement Force XXI through three axes of approach as it prepares to posture itself for future warfare:

1. Heavy Forces
2. Light Forces
3. Strike Force

As expected, the third axis of strike force has caused the most discussion. The Army defines the strike force as a medium-weight, early-entry force and not a forced-entry force (Naylor 1998, 4). However, in Lieutenant General Kernan's interview with the *Field*

Artillery Journal, he points out that there is no reason to explore a third element called strike force if the Army builds on the current organizations of the 82d Airborne and 101st Airborne (Air Assault) Divisions by giving them the appropriate assets to increase their mobility, lethality, and survivability (Kernan 1999, 4).

Major General Scales Jr. describes in "Firepower in Limited War" that victory in a future small-scale war of intervention is won by small groups of well-trained infantry forces employing surgical firepower. Heavy indirect firepower in this type of conflict comes from mortars supporting local assaults. In heavier types of combat, firepower, either direct or indirect, must so overwhelm the enemy that close combat by infantry forces is avoided (Scales 1994, 294).

Putting Lieutenant General Kernan's comments next Major General Scales' reveals the existence of the dichotomy: maneuver versus attrition; suppression versus destruction; light versus heavy; 105-mm versus 120-mm versus 155-mm.

CHAPTER 3

RESEARCH DESIGN

Comparing the 105-mm howitzer against the 155-mm howitzer and 120-mm mortar answers the primary, secondary and tertiary questions of:

1. Should the Future Direct Support Weapon (FDSW) for light forces be a 105-mm howitzer?
2. Are 105mm howitzers better than 120-mm mortars to support light, forced-entry, or strike forces from now until 2010 and beyond?
3. Are 105-mm or 155-mm towed howitzers better suited to support light, forced-entry, or strike forces from now until 2010 and beyond?

The M119A1 Light Howitzer acts as the 105-mm howitzer for analysis (table 3 and figure 3). The M120 Battalion Mortar System acts as the 120-mm mortar for analysis (table 3 and figure 4). Best available data from either the M198 or XM777 UFH acts as the 155-mm howitzer for analysis (table 3 and figure 5).

Table 3. Research Methodology

Weapon Type	Weapon System used for Analysis
105-mm howitzer	M119A1 Light Howitzer
120-mortar	M120 Battalion Mortar System
155-mm howitzer	M198 and XM777 UFH

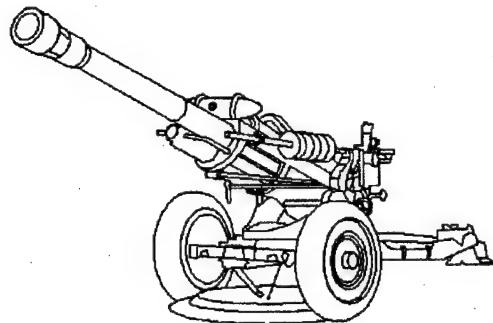


Figure 3. M119A1 105-mm light towed howitzer. Weight is 4,100 pounds without basic issue items. Maximum rate of fire is 6 rounds per minute and sustained rate of fire is 3 rounds per minute (TM 9-1015-252-10 1992, 1-5). Crew size is five personnel (Strahan 1978, 32). Range for high explosive M1 round is 11.4 kilometers (km) (FT 105-AS-3 1994, 208).

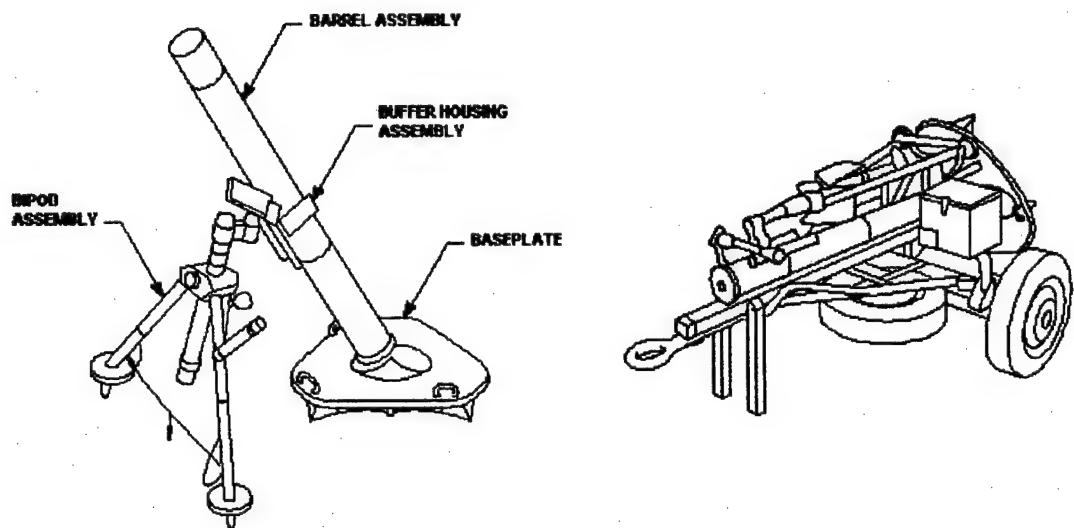


Figure 4. M120 120-mm mortar battalion system (firing and towed configuration). Firing/Towed configuration is 318/716 pounds without basic issue items (PM Mortars 1993). Crew size is four personnel (Strahan 1978, 32). Range for high explosive M934/M933 round is 7,159 meters (FT 120-A-0, C-4 [PROV] 1998, 208). Maximum rate of fire is 15 rounds per minute and sustained rate of fire is 4-5 rounds per minutes (Gardner 1998, 443).

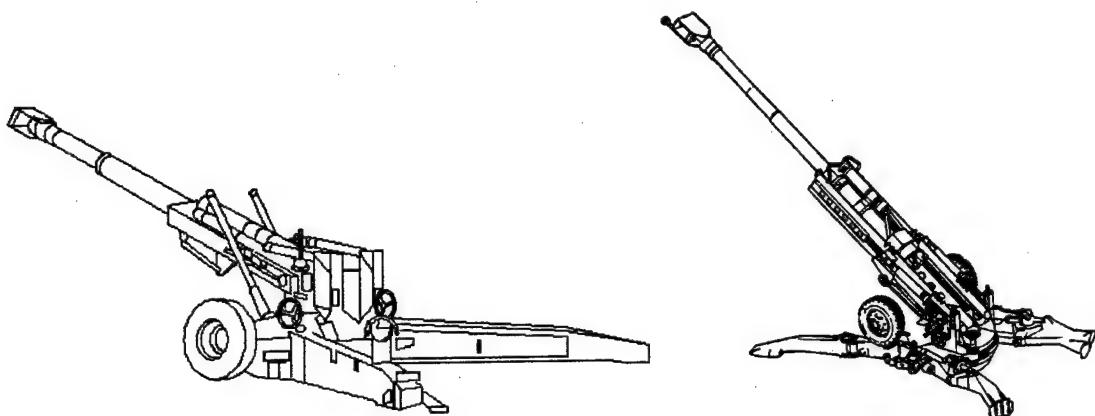


Figure 5. M198 155-mm medium towed howitzer (left) and XM777 Ultralightweight Field Howitzer (UFH) (right). UFH weight is 8,256 pounds without basic issue items. UFH crew size is eight personnel (*Army Technology* [1999]). M198 range for high explosive M107 round is 14.7 km (FT 155-AM-2 1983, 339). Maximum rate of fire is 5 rounds per minute and sustained rate of fire is 2 rounds per minute (*Army Technology* [1999]).

Measurements of Criteria Comparing
the 105-mm howitzer, 120-mm mortar and 155-mm howitzer
against each other

The aggregate criterion measures for comparing weapon systems are lethality, survivability, and mobility (table 4). The tool used to best determine the if the FDSW is a 105-mm howitzer, 155-mm howitzer, or 120-mm mortar is the decision matrix program contained in the Military Application Program Package, administered through the U.S. Army Combined Arms and Service Staff School (CAS3), Fort Leavenworth. The sensitivity analysis subprogram conducts an analysis of how sensitive results are to changes in the values of weights. The selected weights program

analytically selects appropriate weights for each weapon system based on a "pair-wise" comparison of the decision criteria (see table 4 for weight values). A consistency ratio of ninety percent or better verifies accurate decision matrix totals.

Lethality

The five requirements for accurate predicted fire and the JMEMP/WAMS CD-ROM measure lethality. The five requirements for accurate predicted fire are:

1. Target location and size
2. Firing unit location
3. Ammunition and weapon information
4. Meteorological information
5. Computational Procedures

The five requirements for accurate predicted fire review inherent characteristics associated with the weapon system and associated ammunition. The JMEMP/WAMS CD-ROM obtains weapons effects data against a specific target.

Survivability

Reviewing the weapon system's direct fire capabilities and potential exposure to indirect fire detection devices affect the weapon's survivability, and ultimately diminish the firing element's

ability to perform in a direct support role. Using the U.S. Army's AN/TPQ-36 and AN/TPQ-37 Firefinder Radars as a benchmark, reveal vulnerabilities of the 105-mm howitzer, 155-mm howitzer, and 120-mm mortar and their detection probabilities. Crew safety and endurance equate to crew performance. Crew safety includes positioning of personnel and their exposure to blast overpressure as associated with the inherent characteristics of the weapon. Survivability also includes the weapon's characteristics of providing suppressing fires and inherent probable errors affecting rounds impacting in relation to friendly, maneuvering soldiers on the ground as measured by MSD (AR 385-63 1983, Chapter 10 and 11).

Mobility

Mobility of the total weapon system, which includes weight and dimensions, consists of weapon, prime mover, and combat load of ammunition (XVIII Airborne Corps 1997, 1). Air and sea assets measure strategic mobility. Helicopter and prime mover for weapon system determines tactical mobility, while ability of section crew to physically move firing piece in the absence of any type of equipment or machinery determines man-movable criteria (Table 4).

Logic for Determining Weight Values

Lethality

The mission of the field artillery is to destroy, neutralize, or suppress the enemy by cannon, rocket, and missile fires and to integrate

Table 4. Aggregate of Criterion Measurement

Lethality		
<u>Actual Criteria</u>	<u>Weight Values</u> (larger is better)	<u>Ranking</u> (larger is better)
Five Requirements for Accurate Predicted Fire (L1)	3.59	(Weapon given value from three to one)
JMEM/WAMS Effects Modeling (L2)	3.59	"
Survivability		
Direct Fire Capability (S1)	1.86	"
Firefinder Susceptibility (S2)	1.00	"
Crew Performance/Soldier Safety(S3)	1.86	"
Mobility		
Strategic (M1)	1.86	"
Tactical (M2)	1.86	"
Man-Moveable (M3)	1.86	"

all fire support into a combined arms operations (ST 6-50-19, 2-1). The field artillery direct support mission influences both actual criterion measurements of lethality, thus receiving greater weight values than any other criterion.

Direct fire

Overwhelming consensus amongst many resources states importance of the weapon system's ability to conduct direct fire missions. Legal Mix VIII's executive summary emphasizes direct fire capability required for battery defense and force protection (DCSOPS 4, 1997). Standards to achieve direct fire capability must fire at low quadrants of elevations (QE) on targets such as bunkers, fixed fortifications, and buildings (USAFAS n.d., 4-13). Specifications include achieving a flat trajectory up to 2,000 meters at a muzzle velocity of at least 480 meters per second. The hit probability is from 0.80 (XVIII Corps Artillery 1997, 7, 10) to 0.90 against a light armored personnel carrier (Grigsby 1999a).

Recent history provides validation of importance for direct firing capability. During Operation JUST CAUSE in December 1989, 105-mm howitzers from the U.S. Army 7th Infantry (Light) Division fired eighteen rounds at a range of approximately fifteen meters towards a

building during the successful seizure of the Colon DENI Station in Panama (James 1998, 71).

More recently with the planned Haiti invasion in 1994, the 82d Airborne DIVARTY's mission to provide all weather, around-the-clock fire support primarily focused on firing illumination missions and demonstrations with high explosive (HE) rounds in non-built-up areas as part of escalation of force techniques, and also included direct fire missions. The 82d Airborne DIVARTY's M119A1s had the direct fire responsibility against hard and soft targets when no other systems, such as the main guns on Sheridan armored vehicles, were available (Gottardi 1999).

Crew Performance/Soldier Safety

The effects of fatigue on the weapon system crew to provide responsive, direct support fires is critical (Lindsey 1995, 2). Legal Mix VIII identifies the concerns of rate of fire and MSD as inhibitors to support maneuvering forces. These factors ultimately affect the light forces to move in close under covering, indirect fires and attack the target (USAFAS n.d., 3-1). Finally, the Commanding General of the XVIII Airborne Corps emphasizes the importance of suppression (Kernan 1999), which lasts as long as the fires continue (Koba 1997, 9).

Mobility

Overwhelming consensus cites limited mobility, either strategic, tactical, or man-moveable, impacts on light forces having a viable FDSW.

Analysis

The sources for technical data comparing weapon systems came mainly from the following areas:

1. Combat development directorates, program managers (PM), TRADOC systems managers (TSM), and industry providing data pertaining to the weapon type and associated suite of munitions used for comparison
2. XVIII Airborne Corps Artillery
3. 82d Airborne Division Artillery
4. Firing Tables Branch of Army Research, Development, and Engineering Center (ARDEC)
5. *Jane's 1998-1999 Armour and Artillery & Infantry Weapons*
6. Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME), *Joint Munitions Effectiveness Manual (JMEM) Surface-to-Surface World Artillery and Mortars Systems (WAMS) CD-ROM (Version 1.0)*
7. Legal Mix VIII study
8. *Measure of Effectiveness* model used by Lieutenant Colonel Robert W. Strahan, U.S. Marine Corps

9. U.S. Army Command and General Staff College and the Field Artillery School (USAFAAS), Training Command

10. U.S. Army Office of Deputy Chief of Staff for Operations (ODCSOPS)

11. U.S. Army TRADOC Analysis Center (TRAC) - White Sands Missile Range (WSMR)

Data from the JMEM/WAMS CD-ROM determines the optimal number of rounds to achieve specific effects on a target. Target description entries are target category, target, damage criteria, environment, target acquisition device (TAD)/target location error (TLE), and target size. For all effects modeling, these are default entries for a target description that best replicates personnel manning a machine gun position (table 5).

1. Target category. Entry is self explanatory.
2. Target. Entry of crouching in foxhole is most realistic disposition of enemy personnel for first round effects since JMEM/WAMS does posture sequencing.
3. Damage criteria. Entry of five-minute assault means that after the firing of the last round, personnel physically become incapable of performing an assault role within five minutes after being hit. This is a JMEM/WAMS default entry for these evaluated weapon systems. Five

minute assault default is practical for light forces moving from minimum safe distances to target area.

Table 5. JMEM/WAMS Target Description Category Entry Format

Target Description	
JMEM/WAMS Category	Analysis Entry
Target Category	Personnel
Target	Crouching in Foxhole
Damage Criteria	5-min ASSLT
Environment	Open
TAD/TLE	No TAD/0 meter TLE
Target Size	50 meter Radius

4. Environment. JMEM/WAMS offers up to six entries ranging from coniferous forest to jungle tangle. Open terrain environment entry averages flat, rolling hills, and gullies into the effects equation.

5. TAD/TLE. TAD is a function of TLE. TAD is the ability of the element identifying the target to provide the most accurate target location. Certain Army TLEs for TADs are classified.

6. Target Size. Entry is self explanatory.

Table 6. JMEM/WAMS Weapon System Category Entry Format

Weapon System	
JMEM/WAMS Category	Analysis Entry
Projectile	HE or ICM variant
Fuze	Point Detonating and Proximity
Range (from weapon to target)	2/3 and maximum range
Charge	Optimal charge based on range entry
Technique of Fire	Observer Adjusted or predicted
Aimpoint conditions	Target Center
Weapon/Volley	6
Desired Damage	5%

Weapon system entries vary depending on the weapon type and system evaluated. Army Research, Development, and Engineering Center (ARDEC) is still verifying actual technical data for the XM777 UFH, therefore, the M198 surrogates the UFH for JMEM/WAMS modeling. All chosen entries determine optimal selections to achieve greatest effects on target. For this modeling, fewest number of rounds fired determines greatest effects on target.

1. Projectile. Entry of high explosive munition for each weapon is the basic HE round. The 105-mm entry is the M1 HE round. The 120-mm entry fires two different HE projectiles for compatibility with fuzes. The M933 HE fires with the M745 point detonating (PD) fuze and the M934 HE fires with the M734 Multioption fuze. The M933 and M934 have the same ballistic characteristics and bursting charge.

2. Fuze. Entry is the allowable fuze for the specific projectile. For comparisons, all weapons systems fired their point detonating (PD) and proximity set fuzes, which have a one to four meter burst height.

3. Range (from weapon to target). Comparisons used two-thirds of the maximum range and then the maximum range for each weapon system, except the maximum range for the 155-mm howitzer. When common range entry values did not exist amongst weapon systems, rounding to common ranges occurred (table 7).

Table 7. Common Range Entry Values for all Weapon Types

Weapon Type	2/3 maximum range	JMEM/WAMS entry	Maximum range	JMEM/WAMS entry
120-mortar	4,724 meters	5 km	7,159 meters	7 km
105-mm howitzer	7,524 meters	7 km	11.4 km	11 km
155-mm (M198)	9,704 meters	9 km	14.7 km	N/A

3. Charge. Entry is every charge available for that range to determine optimal charge. Charge is also known as propellant or powder. A projectile reaches the target by the power obtained from the propelling charge explosive train (ST 6-50-19 1989, 12-3).

4. Technique of Fire. Entry values are either observer adjusted or predicted. Observer adjusted employs a forward observer (FO) or spotter who adjust the fall of shot onto a target. Theory is based on making successive corrections to weapon aimpoint. JMFM/WAMS applies final correction of observer adjusted technique as first rounds impacting. Predicted fire delivery technique uses the five requirements for accurate predicted fire does not use adjustments for determining gunnery solution for first rounds impacting. Comparison data depicts predicted technique as more accurate (JTCG/ME 1997).

The 120-mm mortar system entry defaults to only observer adjusted. The 105-mm howitzer entry defaults to only predicted. The 155-mm howitzer has the option for both and for analysis comparison, observer adjusted is the entry value.

5. Aimpoint conditions. All three weapon systems have many entry values to choose from to determine the sheaf for rounds impacting on the target. The optimal sheaf for 120-mm mortars is target center. The optimal sheaf for howitzers fluctuates between target center and battery

computer system (BCS) which is a automated process providing a technical fire direction solution for each firing piece for a specific target.

The automated process is the primary source of technical fire direction for howitzers (JTCG/ME 1997).

6. Weapon/Volley. The entry of six replicates the standard number of weapons in a field artillery battery. Six is also used for 120-mm mortars. One volley means the six same weapon systems of a battery firing simultaneously or nearly so at the same target (JTCG/ME 1997).

7. Desired Damage. The entry of 5 per cent best replicates the lethal effects of suppressive fires supporting maneuvering forces in an initially austere light environment. The value is a component of expected fractional damage (EFD) to determine the average fraction of the target elements for an expenditure of n rounds (JTCG/ME 1997).

The results of number of rounds and volleys to achieve desired damage becomes the SECRET-NOFORN portion of JMFM/WAMS. To convert results into ratios for comparisons amongst the weapons systems, the firing piece achieving the greatest effects becomes the value of one. The other weapon systems than are determined by a ratio of rounds fired to achieve the same effects for weapon piece with the greatest effects. In all modeling, the 155-mm achieves the greatest effects. The remaining ratios for a 105-mm howitzer and 120-mm mortar evaluate the

difference from the 155-mm howitzer. Additionally, the ratios for the 105-mm howitzer and 120-mm mortar show the difference in effects against each other.

Summary

The three weapon system platforms consisting of a 105-mm howitzer, a 120-mm mortar, and a 155-mm howitzer have distinct characteristics offering significant differences in capabilities. The criterion measures identify the elements that affect the mission needs required for success on the battlefield to support light forces. The analysis focused on the individual, technical characteristics and capabilities of the weapons system and did not involve tactical wargame models depicting artillery units supporting maneuver forces. The focus of the analysis is to highlight how each weapon system fares against each other by concentration on its ability to have effects on a target and survive on the battlefield.

CHAPTER 4

ANALYSIS

The overall measurements of lethality, mobility, and survivability in comparing the 105-mm howitzer against a 120-mm mortar and a towed 155-mm howitzer to determine which weapon system should become the next FDSW supporting light forces revealed many strengths and weaknesses inherent with the characteristics of each indirect firing platform. The 105-mm howitzer ranked consistently within the competing parameters of evaluation, while the 155-mm howitzer and 120-mm mortar hovered in either the high or low end of the ranking spectrum (see table 8).

Lethality

Five Requirements for Accurate Predicted Fire

The 105-mm & 155-mm howitzers can both achieve all the requirements for delivering predicted fire. The 120-mm mortar achieves all of the requirements for accurate predicted fire except for ammunition and weapon information. The final analysis determines the howitzer achievements are slightly greater than those of the 120-mm mortars. Weighting determines the analysis scores of 7.18 for the 105-mm and 155-mm howitzers and 3.59 for 120-mm mortars.

Table 8. Analysis

Weapon Type	L1(3.59)	L2(3.59)	S1(1.86)	S2(1.0)	S3(1.86)	M1(1.86)	M2(1.86)	M3(1.86)	Total Values
105-mm howitzer	<u>7.18</u>	7.18	3.72	<u>2.0</u>	<u>3.72</u>	3.72	3.72	3.72	<u>34.96</u>
155-mm howitzer	<u>7.18</u>	<u>10.77</u>	<u>5.58</u>	<u>2.0</u>	1.86	1.86	1.86	1.86	32.97
120-mortar	3.59	3.59	1.86	1.0	1.86	<u>5.58</u>	<u>5.58</u>	<u>5.58</u>	28.64

Consistency Ratio is 99.54%

- Top row of table indicates abbreviation for actual criterion measurements with weight values in parentheses.
 - Second through fourth row has shows total values to include weighting. Larger values are better values. Underline values in rows two through four determine highest values for actual criteria.
 - Tenth column shows total values for comparison of analysis.
- L1 - Five Requirements for Accurate Predicted Fire.
 L2 - JMEM/WAMS Effects Modeling.
 S1 - Direct Fire Capability.
 S2 - Firefinder Susceptibility.
 S3 - Crew Performance/Soldier Safety.
 M1 - Strategic (Mobility).
 M2 - Tactical (Mobility).
 M3 - Man-Moveable (Mobility).

Target location and size

Consistent for all three types of weapon systems.

Firing unit location

The advent of surveying technology makes this requirement of determining the most accurate location for a firing piece consistent for all three types of weapon systems. Mortar system development for determining fire control is now becoming comparable with field artillery systems at the fire direction cell and at the individual firing piece location (*Army Weapons And Equipment* [1998], 280). Improving mortar laying procedures to reduce positioning errors and integrating the positioning data into the ballistic solution brings equality with field artillery procedures.

Meteorological information

Consistent for all three types of weapon systems. Improvements to the mortar fire control system will incorporate artillery meteorological messages and input the data into the ballistic solution (Burke 1998, 261).

Computational procedures

Consistent for all three types of weapon systems. Emerging capabilities for the entire mortar linkage of delivering fires will become comparable to field artillery systems.

Ammunition and weapon information

Mortars are unable to achieve this requirement. Interior ballistics deal with the factors that affect the motion of the projectile within the tube (FM 6-40 1996, 3-1). The design of mortar tubes and ammunition causes inconsistency amongst firing of rounds, therefore affecting accuracy and the ability to compensate for errors. Muzzle velocity, which is the speed of the projectile as it exits the tube, is one the most important factors affected by unstable interior ballistics. The muzzle loaded M120 battalion mortar system and future breech loaded mortars will continue to have tubes that are considered smoothbore (Burke 1998, 263) and not rifled as howitzers are. The rifled artillery tube is one of the reasons why artillery has greater range, accuracy, and consistency. The advantage to having a muzzle loaded, smooth bore design, such as the M120 mortar, is the much greater rate of fire as it is easier to load as compared with breech loaded, rifled bore tubes. A rifled bore design eliminates quick muzzle loading capabilities.

The ignition of the propellant within a tube causes gases to move a projectile out towards a designated target. The breech loading process for a rifled tube causes a seal that allows no gases or energy to escape (FM 6-40 1996, 3-4) around the projectile while it moves

through the inside of the tube. A muzzle loaded, smooth bore design causes mortars to have inherent gas leaks or "dirty air" (Whiteside 1999) as the projectile initially goes down the tube (loading) and then moves up and out of the tube (firing) towards a designated target. Varying amounts of propellant gas leak with every firing of a mortar round.

The mortar ammunition also causes this requirement for accurate predicted fire to be unobtainable. The basic design of a mortar round as compared to a howitzer round clearly show the differences (Figure 6).

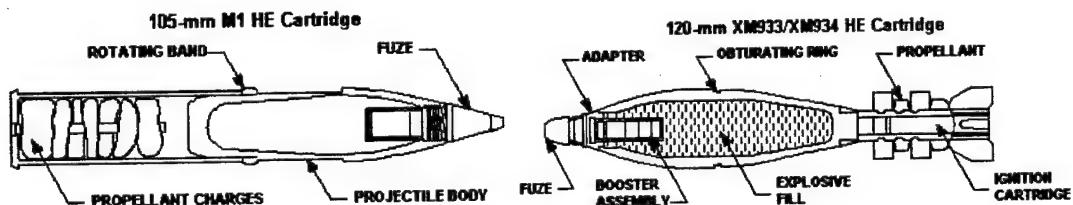


Figure 6. The 105-mm howitzer round (left) and the 120-mm mortar round (right). These rounds are not drawn to comparable scale against each other. A firing tube can achieve a better gas tight seal with the howitzer round as compared to a mortar round's projectile body design and fins.

The propelling charges shown within the cartridge of the 105-mm projectile depict this ammunition as semifixed (figure 4-1). Most 105-mm ammunition is semifixed. All 155-mm projectiles are separate-loading

ammunition where the propelling charges are not within the cartridge of the ammunition (figure 7).

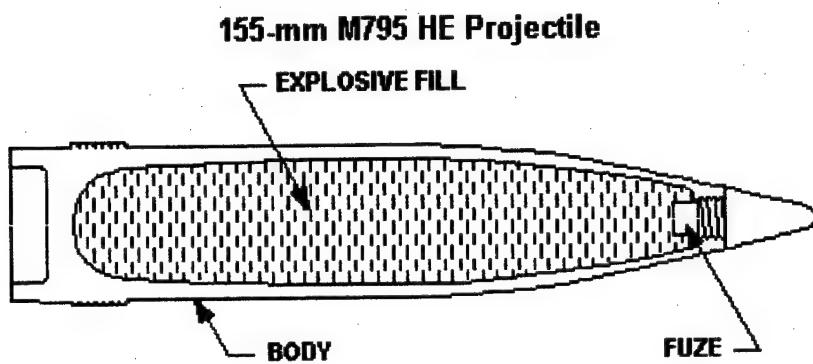


Figure 7. 155-mm round. Placement of separately loaded propellant, or charges, is in the powder chamber of a 155-mm cannon behind the projectile (ST 6-50-19 1989, 2-14).

Additionally, production of mortar rounds are not made to the same measure of specifications as howitzer ammunition. Manufacturing specifications for final assembly of howitzer rounds, to include propellant charges for 155-mm separate-loading ammunition, includes meeting certain tolerances, to include weight differences, and having lots undergo test firing for comparison against other previously produced lots (Whiteside 1999). Accounting for all these ammunition and propellant factors, to include temperature, lead to the final gunnery

solution of applying ballistics to determine the technical data required to hit a target (FM 6-40 1996, 3-1).

Howitzer ammunition specifications control all portions of production. Mortar ammunition has specifications for the production of individual components of the projectile coming from various sources. However, mortar ammunition production does not have an integrating contractor that has total assemble and production responsibilities to verify compliance of standards. Currently, the final element of mortar ammunition only assembles and packs the projectiles (Whiteside 1999). Identifying and tracking the weight of mortar ammunition lots is not done. The simple matter of the weight of a projectile affects the muzzle velocity. A lower weight than standard generally increases the velocity of the projectile (FM 6-40 1996, 3-11), thus causing a slightly longer range than anticipated (Gardner 1998, 753). A higher weight than standard in ammunition causes the inverse effect to occur. Finally, the linkage of mortar systems cannot measure muzzle velocities and apply them to the gunnery solution.

After a round exits a tube, it transfers from interior ballistics to transitional, exterior, and terminal ballistics. Figure 4-1 also shows the most obvious difference between mortar and howitzer ammunition design that affects their performance during all the conditions of

ballistics. The mortar projectile's fins causes it to become fin stabilized while in flight, while the artillery round, which has no fins, is spin stabilized (Whiteside 1999) by the rifled bore of the cannon. Analyzing the criteria of Crew Performance/Soldier Safety under Survivability evaluates the effects of drag and time on the exterior ballistics of the projectiles.

In summary, research revealed that the 120-mm mortars cannot currently achieve the requirement for accurate ammunition and weapon information. The basic mortar ammunition design and production, coupled with the design of the muzzle loaded, smoothbore tube for the 120-mm mortar system cannot allow for consistent tracking of information required to ensure accuracy comparable to the 105-mm and 155-mm howitzers, thus resulting in greater lethality on the battlefield.

JMEM/WAMS Results

The 155-mm howitzer achieved the greatest effects on target for all determined ranges and multiple combinations of shells, fuzes, charges, techniques of fire and aimpoint conditions for each specified range. The 155-mm howitzer's effects were significantly greater than results attained by the 105-mm howitzer and 120-mm mortar. The analysis ranked the 105-mm howitzer higher than the 120-mm mortar, even though the 120-mm mortars achieved greater effects on target than the 105-mm

howitzer up to the mortar maximum modeling range of seven kilometers. The 105-mm howitzer's capability to extend to a maximum range of eleven kilometers is the decisive statistic in its ability to provide direct support indirect fires to a light force in an initially austere environment. The 105-mm howitzer's longer range over the 120-mm mortar provides the maneuver commander the opportunity to engage threat targets out far enough to initiate attrition before those targets become a serious threat in the close-in battle area (USAFAS n.d., 4). Effectiveness results beyond the initial 5% desired damage criteria determined final charge selection for analysis. Weighting determines the analysis scores of 10.77 for 155-mm howitzers, 7.18 for 105-mm howitzers, and 3.59 for 120-mm mortars.

Analysis ranges of 5,000 meters, 7,000 meters, and 11,000 meters depicted the two-thirds planning and maximum ranges for 120-mm mortars and 105-mm howitzers (table 9).

For all comparison analysis, the following entries for target description, desired damage, and number of weapons firing volleys were default values for modeling (table 10). Analysis compared actual proximity fuzes or those capable of functioning in that manner.

Table 9. JMEM/WAMS Range Entry Methodology

Entry Range	120-mortar	105-mm howitzer	155-mm howitzer
5,000 meters	2/3 maximum range	comparison	comparison
7,000 meters	maximum range	2/3 maximum range	comparison
11,000 meters	N/A	maximum range	comparison

Depicting fuze types as proximity in nature and not identifying by nomenclature adds as a precautionary measure from keeping data results unclassified. Chapter Three explains data on available fuzes for comparison. Predicted was the default value for 105-mm technique of fire. The 155-mm and 105-mm howitzers actually achieved greater effects when using the BCS aimpoint conditions for ranges of 5,000 and 7,000 meters. However, current mortar systems' inability to incorporate precision lay firing piece information to determine actual firing piece data excludes BCS results.

Range to target of 5,000 meters

The 155-mm howitzer achieved the greatest effects with the lowest number of rounds fired (table 11).

Table 10. JMEM/WAMS Default Entries

Target Description	
JMEM/WAMS Category	Analysis Entry
Target (TGT) Category	Personnel
TGT	Crouching in Foxhole
Damage Criteria	5-min ASSLT
Environment	Open
TGT Acquisition Device(TAD)/TGT Location Errors(TLE)	No TAD/0 meter TLE
TGT Size	50m Radius
Desired Damage	5% suppression
Weapon/Volley	6

The 120-mm mortar firing the 1.45 ratio or 31% more ammunition achieves parity with a 155-mm howitzer's effects under those conditions.

The 105-mm howitzer firing the 2.98 ratio or 66% more ammunition achieves parity with a 155-mm howitzer's effects under those conditions.

The 105-mm howitzer firing the 2.05 ratio or 51% more ammunition achieves parity with a 120-mm mortar.

Table 11. Range to target of 5,000 meters

Entries	155-mm	120-mm	105-mm
Projectile	HE (M795)	HE (M934)	HE (M1)
Fuze	Proximity type	Proximity type	Proximity type
Charge	5 Greenbags	3	5
Technique of Fire	Observer Adjusted	Observer Adjusted	Predicted
Aimpoint conditions	Target Center	Target Center	Target Center
Ratio of rounds to achieve desired effects	$x/y = \# \text{ of}$ rounds to achieve effects	$1.45 (x) \quad x/y = x/y$ <hr/> $x/y = \# \text{ of rounds}$ to achieve effects	$2.98 (x) \quad x/y = x/y$ <hr/> $2.05 (x) \quad x/y = x/y$

Range to target of 7,000 meters

The 155-mm howitzer achieved the greatest effects with the lowest number of rounds fired (table 12).

The 120-mm mortar firing the 1.73 ratio or 42% more ammunition achieves parity with a 155-mm howitzer's effects under those conditions.

The 105-mm howitzer firing the 3.80 ratio or 73% more ammunition achieves parity with a 155-mm howitzer's effects under those conditions.

The 105-mm howitzer firing the 2.19 ratio or 54% more ammunition achieves parity with a 120-mm mortar.

Table 12. Range to target of 7,000 meters

Entries	155-mm	120-mm	105-mm
Projectile	HE (M795)	HE (M934)	HE (M1)
Fuze	Proximity type	Proximity type	Proximity type
Charge	5 Greenbags	4	7
Technique of Fire	Observer Adjusted	Observer Adjusted	Predicted
Aimpoint conditions	Target Center	Target Center	Target Center
Ratio of rounds to achieve desired effects	$x/y = \# \text{ of}$ rounds to achieve effects	$1.73 (x) \quad x/y = x/y$ <hr/> $x/y = \# \text{ of rounds}$ $\text{to achieve effects}$	$3.80 (x) \quad x/y = x/y$ <hr/> $2.19 (x) \quad x/y = x/y$

The ARTQUICK model for determining effects uses all available information provided from various agencies within Army Material Systems Analysis Activity (AMSAA). Much of the technical data for determining ballistics comes specifically from the Firing Tables Branch. During the

effects modeling with the JMEM/WAMS CD-ROM, a downward trend in percentages of effects occurs with 120-mm mortars with increased charges or ranges. For instance, the increase in 120-mm rounds to obtain the same effects as the 155-mm howitzer from 5,000 meters to 7,000 meters is 38%. The increase in 105-mm rounds to obtain the same effects as the 155-mm howitzer from 5,000 meters to 7,000 meters is 29%. The increase in 105-mm rounds to obtain the same effects as the 120-mm mortar from 5,000 meters to 7,000 meters is 25% (table 13).

Further analysis of firing tables for both the 105-mm howitzer and the 120-mm mortar revealed that the mortar's probable errors in range ($P_E R$) and deflection ($P_E D$) are so large to begin with, any change in propellant zone or range has a much more drastic effect. On average, the 120-mm mortar has a 14 $P_E R$ and 16 $P_E D$ larger differential than 105-mm howitzers.

Table 13. Percentage increase for greater ranges to achieve same effects as 155-mm howitzer

Weapon Systems	Increase in % from 5km to 7km to achieve same effects as 155-mm howitzer	Increase in % from 5km to 7km to achieve same effects as 120-mm mortar
105-mm howitzer	29%	25%
120-mm mortar	38%	N/A

Range to target of 11,000 meters

Again, the 155-mm howitzer achieved the greatest effects with the lowest number of rounds fired. The 105-mm howitzer firing the 2.9 ratio achieves parity with a 155-mm howitzer's effects for optimal conditions of using BCS and type of shell and fuze combination, to include data available on the M916 105-mm DPICM round versus the 155-mm M843A1 DPICM. The 2.9 ratio tracks comparably with the USAFAS unclassified 2.8 composite lethality ratio (Grigsby 1999).

Survivability

Direct Fire

The 105-mm & 155-mm howitzers can both conduct feasible direct fire missions in accordance with the specifications of firing a projectile with a muzzle velocity of at least 480 meters per second. The breech loading design of the M120 battalion mortar system, the lack of a recoil mechanism, and no direct fire sight (Whiteside 1999) eliminate the 120-mm mortar from enabling it to conduct a direct fire mission. Breech loading and no recoil mechanism do not allow the mortar tube to get depressed a quadrant elevation below forty-five degrees. A recoil mechanism also absorbs the energy from such a high velocity fire mission. The 120-mm mortar's highest muzzle velocity is 323 meters per second at charge four (FT 120-A-0, C-4 [PROV] 1998, 69), way below the

480 meters per second threshold (XVIII Corps Artillery 1997, 7). The lower velocity affects the stability of the round in a flat trajectory and would decrease the probability of penetrating hard targets such as bunkers, fixed fortifications, and buildings (Whiteside 1999). Testing also determined that a 120-mm mortar cannot achieve a first round hit probability of 0.90 against a light armored personnel carrier (Grigsby 1999a) or a stationary North Atlantic Organization Treaty (NATO) standard sized target (2.5 by 2.5 meters) with a HE projectile (XVIII Corps Artillery 1997, 7, 10).

A 105-mm howitzer has a proven past to achieve this capability. A charge seven muzzle velocity of 493 meters per second (FT 105-AS-3 1989, 187) exceeds the 480 meter per second requirement. Testing also validated that a 105-mm howitzer can achieve a first round hit probability of 0.90 against a light armored personnel carrier (Grigsby 1999a). 105-mm also howitzers have the suite of munitions to conduct direct fire missions (Grymes 1998). These requirements for direct fire capability for the 105-mm howitzer still exist with the recent deletion of the improved direct fire scope (USAFAS 1998b) providing greater magnification and night vision capability, as identified under block two of the light artillery system improvement plan (LASIP) (Mullins 1998, 2).

The 155-mm howitzer attains a muzzle velocity of 568 meters per second with charge seven white bags (FT 155-AM-2 1983, 311). Testing also validated that a 155-mm howitzer can achieve a first round hit probability of 0.90 against a light armored personnel carrier (Grigsby 1999a).

The final analysis determines that a 155-mm howitzer's direct fire capability is greater than those achieved by a 105-mm howitzer, and significantly greater than a 120-mm mortar. Weighting determines the analysis scores of 5.58 for the 155-mm howitzer, 3.72 for a 105-mm howitzer, and 1.86 for 120-mm mortar.

Firefinder Susceptibility

Inherent characteristics associated with 120-mm mortars make them most susceptible to acquisition devices because of their maximum ordinate (MO) and time of flight (TOF). Averaging the total number of missions with their associated MO for all missions fired in the JMEM/WAMS effects modeling, 120-mm mortars were on average 1,809 more meters, or 5,935 feet, in elevation as compared to both 105-mm and 155-mm howitzers. Average MO for mortars was 2,330 meters while the 105-mm and 155-mm howitzer's averaged 521 meters. Additionally, the mortar average TOF range was from twenty-four to twenty-eight seconds longer than the TOFs for 105-mm and 155-mm howitzers. The mortar average TOF

was forty-six seconds while the 105-mm and 155-mm howitzers were 20.4 seconds (table 14), (FT 155-AM-2 1983; FT 105-AS-3 1989; FT 120-A-0, C-4 [PROV] 1998).

Table 14. JMEM/WAMS Effects Modeling Exterior Ballistic Characteristics

Weapon Type	Average MO	Average TOF
120-mm Mortar	2,330 meters	46 seconds
105-mm & 155-mm Howitzer	521 meters	20.4 seconds

Additional analysis using the U.S. Army's AN/TPQ-36 and AN/TPQ-37 Firefinder Radars in the hostile mode highlight detection probabilities for each weapon system. The mission of the AN/TPQ-36 is to locate enemy mortar and shorter range artillery firing positions focusing on shorter-range, high-angle, low-velocity indirect firing systems. The AN/TPQ-37's mission is to locate enemy artillery and rocket, firing positions focusing on longer-range, low-angle, higher-velocity indirect firing systems. However, the AN/TPQ-37 has the limited capability to locate shorter-range, high-angle, low-velocity indirect firing systems (Shealy 1998, 1).

JMEM/WAMS range entry values (table 15) are the basis for determining detection probabilities for the AN/TPQ-36 and Q-37, with the assumption of meeting all requirements for successful detection. Table 15 groups the 105-mm and 155-mm howitzers together because there is no significant difference in their firefinder vulnerability. The AN/TPQ-36 and Q-37 detect the 120-mm mortars at a greater rate than the 105-mm and 155-mm howitzers. The AN/TPQ-36 detection probability rates are with the "video integration" mode "on." Heavy artillery and rocket detection are the primary weapon system objectives for the design of the AN/TPQ-37 and not light to medium sized artillery such as the 105-mm and 155-mm howitzers used for modeling.

Table 15. Firefinder Radar Detection Probabilities
within Modeling Ranges

Weapon Type	AN/TPQ-36 Detection Probability	AN/TPQ-37 Detection Probability
120-mm Mortar	90%	90%
105-mm & 155-mm Howitzer	70%	85%

(Shealy 1998, 7)

The muzzle velocities for the 120-mm mortars and 105-mm and 155-mm howitzers fall well within the tracking parameters for both the AN/TPQ-36 and Q-37 Firefinder radar when in the hostile mode. Operations in the hostile mode detect projectiles from enemy weapon systems during their ascending trajectory. The AN/TPQ-36 uses approximately 80 mils and the AN/TPQ-37 uses approximately 104 mils to establish a vertical scan to track these ascending trajectories. A successful plot normally requires a minimum of 50 mils to track the ascending projectile. The AN/TPQ-36 needs approximately 3 to 5 seconds, while the AN/TPQ-37 needs 5 to 8 seconds, to successfully achieve the minimum track of 50 mils to plot the projectile's ballistic path. Table 14 highlights the 120-mm mortar's inherent MO and TOF characteristics, therefore increasing its vulnerability to a successful plot and subsequent track in determining the hostile weapon's location and predicted impact point (Shealy 1999, 2). The 120-mm mortar's greater TOF occurs because of the higher trajectory (Briggs et al. 1997, 35), as compared to the 105-mm and 155-mm howitzers, exposing the mortar projectile for a longer period of time for weapon locating radars. The MO and TOF factors, coupled with technology proliferation throughout the world, allow most nations who may be of a future threat to the United States to acquire single round

Locating radars (XVIII Airborne Corps Artillery 1997, 2) best suited against the 120-mm mortar.

The five requirements for accurate predicted fire criteria explained why mortars are an inherently inaccurate weapon as compared to howitzers. Acquiring mortars not only exposes them to a counterfire threat, but more realistically, allows targets to flee or improve posture and protection by the advance warning of their radar. Additionally, the inaccuracy of mortars may result in repeat missions toward the same target after adjustments have been made. These repeat missions due to inaccurate first time hits and subsequent advance warning, causes overall effects to decrease as compared to howitzers.

The final analysis determines that the 105-mm and 155-mm howitzers rank higher than the 120-mm mortar because of the inherent characteristics associated with each howitzer and mortar system. No weighting occurred for this criteria because of the belief that all indirect fire weapon systems are equally susceptible to weapons finding radar (Soby 1999). The final analysis determines that both 105-mm and 155-mm howitzer's are equally less susceptible than a 120-mm mortar. The analysis scores for 105-mm and 155-mm howitzers are 2.0 and 1.0 for 120-mm mortars.

Crew Performance/Soldier Safety

Final analysis rates the 105-mm howitzer greater than 120-mm mortars and 155-mm howitzers, which are both equal to each other. Weighting determines the analysis scores of 3.72 for the 105-mm howitzer and 1.86 for 120-mm mortars and 155-mm howitzers. The approximate thirty pound weight of the 120-mm mortar fuzed projectile (FT 120-A-0, C-4 [PROV] 1998, V) and the approximate thirty-four pound weight of the 105-mm howitzer fuzed projectile (FT 105-AS-3 1989, VI) are significantly less than the approximate combined 113 pounds for a 155-mm fuzed projectile and associated propellants (Hood 1998, 3). The weight of the projectiles affect the fatigue of the section crew to function towards performing indirect fire missions and to internally move ammunition in and around the actual weapon system. The approximate 94.5 pounds of a 155-mm projectile alone (FT 155-AM-2 1983, XI), taxes the upper strength of any soldier or artilleryman conducting routine handling of ammunition (Lindsey 1995, 2). Combining the larger weight ammunition of 155-mm projectiles with the concept of "shoot and scoot tactics" requiring numerous occupations and displacements, for indirect fire systems, effects the overall ability of the section crew to operate under twenty-four hour conditions and safely provide responsive and

accurate fires (Hood 1998, 3). Those same conditions do not affect the section crews manning a 120-mm mortar and a 105-mm howitzer.

Another safety dimension towards the safety of the section crew is the exposure to blast overpressure. Howitzer's breech loading design reduces the exposure while the 120-mm mortar's muzzle loading design places section crew members in higher levels of exposure in the surface danger zone (SDZ) of area E (AR 385-63 1983, 11-4). Howitzers have the option to use a twenty-five foot lanyard to fire the weapon for certain conditions to include removing personnel from any exposure to blast overpressure (TM 9-1015-252-10 C3 1994, c, d). Additionally, firing procedures for specific conditions concerning howitzer and mortar section crews affect their safety. If the tactical situation requires weapon systems to conduct maximum rates of fire, mortar crews are more susceptible to danger by inadvertently loading a round before a previous round leaves the mortar tube (TM 9-1015-249-10 1987, C2 i). Misfire and checkfire procedures for howitzers also reduce the exposure of risk for the section crews as compared to mortar section crews. Mortar section crew drills have personnel in SDZ area E for retrieval of a round for misfire procedures (TM 9-1015-249-10 1987, 2-76).

Firing capabilities also affect friendly, maneuvering personnel located vicinity of rounds impacting. The analysis criterion of

L lethality and Firefinder Susceptibility explain the inherent characteristics of how howitzers are more accurate than mortars, and the inordinate TOFs of mortar rounds, respectively. During the effects modeling with the JMEM/WAMS CD-ROM, the relation of decreased TOF caused greater effects on targets became apparent. This trend usually held true for every charge selection except for the highest zones in artillery ammunition. For instance, for a specified range, increasing charges reduces TOF and PER and PED, resulting firing less rounds, thus having greater effects (table 16). In most cases, the same holds true for 120-mm mortars (table 17).

Table 16. 105-mm howitzer relation of decreased time of flight (TOF) with greater effects on target

Charge	PER	PED	TOF	JMEM/WAMS Effects Results
3	32	3	28.3	1.18 (x) $x/y = x/y$
4	27	2	22.0	1.12 (x) $x/y = x/y$
5	15	2	18.4	$x/y = \#$ of rounds to achieve effects

(Value entries from FT 105-AS-3 1989)

Exterior ballistics is the science that deals with factors affecting the motion of a projectile after it leaves the muzzle of a firing weapon (FM 6-40 1996, 3-12). The function of time affects three factors of exterior ballistics which are drag, temperature, and wind (Rigano 1999). Drag is the resistance of the atmosphere to a projectile moving through it (FM 6-40 1996, Glossary-4). The longer the projectile is in the air, TOF, the greater affects of drag, temperature, and wind have on the accuracy of the round impacting on "should hit" data. These

Table 17. 120-mm mortar relation of decreased time of flight (TOF) with greater effects on target

Charge	PER	PED	TOF	JMEM/WAMS Effects Results
2	31	11	41.3	$x/y = \# \text{ of rounds to achieve effects}$
3	27	20	47.4	1.46 (x) $x/y = x/y$
4	24	26	55.2	1.61 (x) $x/y = x/y$

(Value entries from FT 120-A-0, C-4 [PROV] 1998)

implications impact on restricting mortars from firing overhead of unprotected troops and determining MSDs (AR 385-63 1983, 10-1). There are various formulas for determining MSDs dependent on the gun-target

line in relation to friendly maneuvering troops vicinity of rounds impacting (figure 8).

Figure 8. Minimum Safe Distance (MSD) formula

$$MSD = SFD \text{ area (A,B, or C)} (+) [n (x) P_E R \text{ or } P_E D]$$

Legal Mix VIII's final recommendation states that the ULW 155's selection as the FDSW provided a viable alternative to all negative aspects cited as concerns except for providing danger close fires (USAFAS n.d., 3-1, 3-2). The overhead restriction on mortar firing and their associated large $P_E R$ and $P_E D$, and the larger caliber of the 155-mm howitzer's affect on the determining MSDs, rate 105-mm howitzers best in providing the least amount of risk to friendly, maneuvering soldiers vicinity the impact area. The 105-mm howitzer's capabilities correspond with light force requirements for indirect, suppressive fires (Kernan 1999, 2).

Mobility

The size and weight of the 120-mm mortar, to include ammunition, is significantly less than for the 155-mm howitzer, and also less than for the 105-mm howitzer. Weighting determines the analysis scores of 5.58 for the 120-mm mortars, 3.72 for the 105-mm howitzer, and 1.86 for

the 155-mm howitzer for actual criterion of Strategic, Tactical, and Man-Moveable, under Mobility. The prime mover vehicle for the 120-mm mortar and the 105-mm howitzer is the high-mobility multipurpose wheeled vehicle (HMMWV). Various types of HMMWVs and their associated curb weight exist depending the tow load for the vehicle.

Strategic

The C-130 aircraft is the smallest strategic, capable asset within the U.S. military of deploying a FDSW. Therefore, the C-130 provides the basis for comparing weapon systems against each other for strategic deployment purposes (XVIII Airborne Corps Artillery 1997, 4). C-130 planning factors for a standard thirty-two foot, Type V platform possess a weight capacity of 20,600 pounds (Hood 1998, 1). The planning weight for the HMMWV is 4,200 pounds (Cummins 1997, 4). The planning weight for the M120 battalion mortar system in the towed configuration is 716 pounds (PM Mortars 1993), and approximately thirty pounds for a fuzed projectile (FT 120-A-0, C-4 [PROV] 1998, V). Strategically deploying 120-mm mortars under available sortie planning conditions currently existing for 105-mm howitzers, weight and dimensions are not an issue for the M120 battalion mortar system.

Currently, a C-130 carries a thirty-two foot, Type V platform which carries the M119A1 howitzer and its prime mover the M109A1 HMMWV.

The load can consist of a minimum of sixty 105-mm rounds or a maximum of seventy-four 105-mm rounds. The planning weight for the M119A1 howitzer, to include basic issue items, is 4,200 pounds (Hood 1998, 1). The 105-mm fuzed projectile weighs approximately thirty-four pounds (FT 105-AS-3 1989, VI). Current U.S. Air Force sortie availability conditions support this strategic deployment package.

The 155-mm XM777's planning weight is weight is 8,256 pounds (*Army Technology* [1999]) and its prime mover is a family of military tactical vehicles (FMTV). Estimates predict the FDSW with a 155-mm cannon can weight as low as 5,000 pounds. However, no current HMMWV can tow that payload. Legal Mix VIII study's recommendation for the ULW 155 is not feasible unless the Army can develop and field a suitable prime mover (USAFAS n.d., 3-1) with the weight much less than those towing current 155-mm towed howitzers.

Tactical

Analyzing tactical mobility includes ground and helicopter assets. The weight and ammunition for the 120-mm mortar are considerably lower than for the M119A1 howitzer. Identifying the requirements for the M119A1 details the current threshold for determining if the FDSW is either a 105-mm or 155-mm howitzer. The ground mobility vehicle used as the prime mover for comparison is the M119A1 howitzer's M1097A1 HMMWV.

Medium lift helicopters are capable of tactically moving the FDSW on future battlefields, however, analysis comparison uses the UH-60L Blackhawk, the smallest utility helicopter in the U.S. military. Light forces either possess or rely on the UH-60L more than the other medium lift category helicopters.

The gross vehicle weight for the M1097A1 HMMWV is 10,000 pounds. The limit of capacity is 8,500 pounds for both the payload and the towed load. Subtracting 4,200 pound for the M119A1 leaves 4,300 pounds for carrying personnel and section equipment, to include classes of supply. Limited only by cube space, the M1097A1 could carry a maximum of sixty 105-mm rounds. Currently, the M1097A1 could not tow a 155-mm, 5,000 pound FDSW because the maximum towing load is 4,200 pounds. Assuming, modifications were made to the M1097A1 HMMWV and it could tow a 155-mm, 5,000 pound FDSW, the maximum of number of 155-mm rounds for carrying is ten to twelve (Hood 1998, 2).

The UH-60L helicopter is capable of carrying an 8,000 pound payload. However, the maximum planning weight of the UH-60L helicopter is 7,000 pounds. The 1,000 pounds variance accounts for weather conditions and aircraft fuel. Currently, UH-60L helicopters can carry section crew, associated equipment (Hood 1998, 2), and a maximum of approximately forty 105-mm rounds.

Much analysis for the a 155-mm FDSW uses estimates involving the UH-60X, the next generation Blackhawk helicopter, and two helicopters for each howitzer section, allows transporting the prime mover and howitzer together. Conducting the mission of an artillery raid is the analysis used for tactical mobility with a UH-60L, where deploying prime movers are normally not done (2-319th AFAR 1996). Dependence upon future development of the UH-60X helicopter possessing an increased payload is sensitive to funding or developmental delays (Hood 1998).

Man-moveable

Analyzing this requirement focused on the section crew's capability to physically manipulate and prepare the weapon system to conduct fire missions. Again, the weight and ammunition for the 120-mm mortar are considerably lower than those for the 105-mm and 155-mm howitzers. Analysis focuses on the demands required of sections manning a 105-mm howitzer versus a 155-mm howitzer.

An airborne operation consisting of putting a firing weapon system into action to conduct firing missions best captures the increased weight demands on a section crew. The requirement to have a weapon system ready to fire has an objective of eleven minutes with a threshold of eighteen minutes for day time operations. The same requirement for hours of limited visibility, or night, has an objective of eighteen

minutes and a threshold of twenty-five minutes (XVIII Airborne Corps Artillery 1997, 4). The increased weight from M102 105-mm howitzer of 3,300 pounds to the current M119A1's weight of 4,200 pounds has put accomplishing those day and night standards on the threshold level. Adopting a 155-mm howitzer as a FDSW will with its minimum weight of 5,000 pounds will push the drop zone mission standards out of compliance.

Additionally, a damaged and unusable prime mover does not prevent the section crew from accomplishing drop zone mission time standards. Historical trends show that a 155-mm FDSW weighing 5,000 pounds would make accomplishing drop zone time standards difficult.

The 1998 Army After Next Annual Report describes mobility operations in urban terrain (MOUT) describes an environment of "urban clutter and restricted pathways." (TRADOC 1998) A 105-mm howitzer's dimension and weight operating in this type of environment easier than with a 155-mm howitzer.

Summary

The 105-mm howitzer finished with a total ranking value of approximately two points higher than the 155-mm howitzer, which was approximately four points higher than the 120-mm mortar (see table 8). The ranking values included specific weighting for each of the overall

eight categories. The 155-mm howitzer actually ranked first, or tied for first in four categories, while the 105-mm howitzer and 120-mm mortar ranked first, or tied for first, in three categories. However, the 155-mm howitzer ranked third in three categories and the 120-mm mortar ranked third in two categories, while the 105-mm howitzer had no third place rankings. Finally, the 105-mm howitzer prevailed by ranking second, or tied for second, in five categories against the 120-mm mortar ranking second, or tied for second, in three categories, while the 155-mm howitzer had one second place ranking. These individual rankings depict that while the 120-mm mortars had the highest capability in mobility-strategic, tactical, and man-moveable; its overall standing suffered by its poor showing in lethality-meeting all five requirements for accurate predicted fire and JMEM/WAMS effects modeling; direct fire capability and firefinder susceptibility. As expected the 155-mm howitzer ranked strongly in all areas of lethality, to include direct fire capability, but ranked third in all areas of mobility. This left the 105-mm howitzer's capabilities as the next best alternative behind the mortars for all areas of mobility, and behind the 155-mm howitzer for overall lethality (table 18).

Table 18. Overall Analysis Category Rankings

Analysis Rankings	105-mm Howtizer	155-mm Howtizer	120-mm Mortar
First Place Ranking	1	2	3
First Place Ranking (tie)	2	2	-
Second Place Ranking	5	1	2
Second Place Ranking (tie)	-	-	1
Third Place Ranking	-	3	2

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Why the Difference of Opinions?

Major General Robert H. Scales, Jr., current Commandant of the U.S. Army War College, writes of future warfare emphasizing initial, precise weapon effects so lethal against an enemy that the fighting never progresses towards the level of close-in battle (Scales 1994, 294). Lieutenant General William F. Kernan, current Commanding General XVIII Airborne Corps, speaks of improving the linkage of the joint battlefield to synchronize all available assets to mass effects in support of soldiers fighting in deep enemy territory (Kernan 1998, 3, 4). Major General Scales interpretation of warfare describes the lethality brought upon by a 155-mm FDSW, emphasizing a battlefield of attrition. Lieutenant General Kernan describes an operational level of fighting based on maneuvering where the focus is on defeating rather than destroying the enemy (U.S. Army Command and General Staff College 1999, 46), conditions best suited for a 105-mm howitzer and/or 120-mm mortar as the FDSW.

The 105-mm howitzer should be the FDSW. Final analysis revealed that a 105-mm howitzer has respectable firing capabilities suitable for light forces in an austere environment. This final analysis did not

include enhanced munitions as part of the evaluating process. Improving munition capabilities for 105-mm howitzers to a level comparable to those possessed or in development for 120-mm mortars and 155-mm howitzers would bring increased lethality suitable for a future battlefield. Most responses from the light forces' community support a 105-mm FDSW that is lighter and technically improved with available technology than the current M119A1 howitzer. Ammunition development for the 105-mm howitzer could improve with efforts from the Special Operations Command's (SOCOM) desire to develop and field smart munitions to support their weapon systems that fire 105-mm projectiles (USAFAS n.d., 4-19).

Until then, vast mortar improvements and concepts are maneuver's responses to fill the lethality void currently existing with the M119A1. Improving artillery lethality by increasing the cannon to a 155-mm howitzer is not the proper response.

105-mm howitzers better suited than 120-mm mortars

Chapter 4 reveals that the 120-mm mortar can accurately achieve four of the five requirements for accurate predicted fire-target location and size; firing unit location; meteorological information; and computational procedures; but cannot attain accurate ammunition and weapon information. The basic 120-mm mortar ammunition design with fins

and a shape that disallows for a gas tight seal to occur within the mortar tube, coupled with the lack of an integrating contractor for mortar ammunition production to ensure technical specification compliance, causes the inconsistencies of attempting to track accurate ammunition information. The 120-mm smooth bore tube design does allow for a higher rate of fire, but also contributes towards the inability to consistently track weapon information by not allowing for a gas tight seal to occur within the tube, resulting in a decreased range and accuracy for the 120-mm mortar versus the 105-mm howitzer. The 120-mm cannot conduct direct fire missions because of its muzzle loaded design that has no recoil mechanism, resulting in the omission of a direct fire sight. Additionally, the 120-mm mortar cannot attain muzzle velocities in excess of 480 meters per second, the threshold required to effectively achieve direct fire target engagement effects. The 120-mm mortar's high trajectory resulting with a greater TOF, causes it to become more susceptible to weapon locating radar. Finally, the substantial range limitations of the 120-mm mortar as compared to the 105-mm howitzer, would require positioning the 120-mm mortar approximately three kilometers behind the forward line of own troops (FLOT) to fire only approximately four kilometers beyond it(Grymes

1998). All of these disadvantages outweigh the 120-mm mortar advantages in mobility over the 105-mm howitzer.

Advanced, carrier mounted, breech loading, mortars with increased tube calibers will be capable of closely achieving predicted fire with greater ranges, and conducting direct fire missions (Burke 1998, 261). However, until the production of mortar ammunition compares to artillery ammunition production by having an integrating contractor, mortars will not fully be able to achieve all requirements for accurate predicted fire (Whiteside 1999).

Weight of FDSW 155-mm howitzer and ammunition
not suited for light forces

A five thousand pound, 155-mm FDSW weapon possesses a twenty-six caliber tube, achieving a maximum range of 14 kilometers for the M483A1 DPICM round. The M483A1 range is comparable to the 105-mm M916 DPICM round which has an improved, charge 8 range of 14.2 kilometers. The development of the XM982 DPICM round which extends the range for a twenty-six caliber, 155-mm tube to 21.1 kilometers. However, the emphasis should focus on developing a 105-mm round comparable range to the XM982. Having this range in a 105-mm round would minimize the collateral damage (Gottardi 1999).

Regardless of emerging technologies to reduce the weight of a 155-mm howitzer (Tabor 1998, 424), ammunition basic load and subsequent

resupply would require much higher ammunition hauling capacity from the field artillery battery to the forward support battalion within a light division (Hood 1998, 3). In a forced entry situation, delivering initial resupply occurs by containerized delivery systems (CDS). The difference in ammunition amounts is per CDS bundle is thirty-two 105-mm rounds versus ten 155-mm rounds. A C-130 dropping its maximum load of 16 bundles equate to 512 105-mm rounds or 160 155-mm rounds (Hood 1998, 3). The added weight required for light forces to move 155-mm munitions would affect how light forces fight in combat (Kellogg 1999).

Initially, Army developers were setting the target weight for the FDSW 155-mm howitzer at approximately 5,000 pounds. However, developers are now attempting to lower the FDSW 155-mm howitzer to below 5,000 pounds. (USAFAFS 1998a, 1) Additionally, there is research exploring the reduction of 155-mm ammunition down from approximately 95 pounds (without propellant) to an estimated 75 pounds (Grigsby 1998b).

Even though the 155-mm FDSW can kill 24 percent more enemy combat systems with 54 percent less ammunition, (USAFAFS 1998b, 3) the slower rate of fire to produce suppression effects places a greater reliance on mortar systems. (USAFAFS n.d., 3-1)

Emerging technologies can reduce the weight of the 155-mm FDSW and associated ammunition to manageable levels and not hamper light forces'

ability to wage combat. However, the Army should those same emerging technologies and reverse the trend of light artillery becoming heavier and develop at least a lighter 105-mm howitzer. Adopting a 5,000 pound, 155-mm FDSW increases the weight of the light howitzer thirty-four percent since the active forces end of service life for the M102 105-mm howitzer.

Emerging technologies have not yet developed a ground tactical vehicle or a utility lift helicopter to support a 155-mm FDSW. The cancellation of the AGS should remind key leaders of the risk associated with basing a weapon system on future concepts.

To satisfy both sides of the 105-mm versus 155-mm debate, Army developers proposed a FDSW that has the capability to have its tube changed out with either a 105-mm or 155-mm cannon tube insert, based on mission, enemy, terrain, troops, and time available (METT-T). (USAFAS 1998a, 1) Such an option would continue to constrain the already limited support tail experienced by light forces. Evaluating a scenario to actually change out a cannon from either a 105-mm to a 155-mm, or vice-versa, in a fluid, battle environment is inconclusive.

Future Discussions

Brigadier General Larry D. Gottardi, current Commanding General XVIII Airborne Corps Artillery, ponders that our military may need to look at a different size of cannon to support light and special purpose forces that is larger than 105-mm but smaller than 155-mm. Brigadier General Gottardi's experience leads him to state that a suitable cannon size would probably be in the 120-mm to 130-mm range, thus causing 120-mm mortar proponents to argue that a weapon system platform capability currently exists. However, this FDSW with a cannon size ranging from 120-mm to 130-mm would have to have all of the inherent characteristics of a howitzer for the capabilities of range and accuracy in order to fix and suppress the enemy and allow maneuver and attack aviation, with contributing indirect fires, to kill the enemy (Gottardi 1999).

The United States Marine Corps experimented with a naval 5-inch (127-mm) cannon on a D-30 howitzer chassis, because the D-30 chassis is arguably one of the most stable and efficient towed systems in existence (Briggs 1999). Major David Briggs, formerly of the Department of Systems Engineering at the United States Military Academy, led a capstone systems engineering design project in 1997 to develop a virtual prototype of the 5"/D-30. Even shortening the carriage by 4 inches to fit naval transport assets (Briggs 1999), the virtual prototype still

weighed in excess of over 10,000 pounds (Briggs et al. 1997, 49).

Today, emerging technologies could possibly lower the weight for such a prototype to exist and fire the U.S. Navy's all weather, around-the-clock 5-inch Extended Range Guided Munition (ERGM) that has an internal guidance system and can exceed ranges five times that of today's cannons (Komarow 1998, 22A).

The U.S. Army must have a redesign in ownership of all indirect firing system platforms. The U.S. Army should continue to have the Infantry Branch be the proponent branch controlling 60-mm, 81-mm, and the M120 mortar battalion system. However, once mortars become breech loaded or have rifled tubes, their proponent branch would then become the Field Artillery. Mortars are approaching the "shoot and scoot" technique of delivering fires. (Whiteside 1999) This capability of maneuvering fire support assets on the battlefield would have greater effects from massing if centralized by a field artillery command and control node. If the Enhanced Fiber-Optic Guided Missile (EFOG-M) gets approval funding, that weapon system should also become a proponent of the Field Artillery branch. Field artillery units would centralize the clearance of fires and deconfliction of airspace (Cutler 1999) for all surface to surface assets of ranges greater than 8 kilometers.

This proposal counters against a future reorganization that suggest artillery assets of 155-mm howitzers and HIMARS control a light division's deep fight, while all mortars at the maneuver brigade and battalion task force level fight the close, indirect fire fight (Soby 1999).

Finally, whatever the type of indirect fire weapon system our military decides to field to support light forces in the twenty-first century, it must be capable of engaging targets at greater ranges, with greater, more predictable effects; able to respond quickly, around-the-clock regardless of weather conditions and effects at a very high operational tempo, possessing the mobility and flexibility equal to that of the force it supports (Gottardi 1999).

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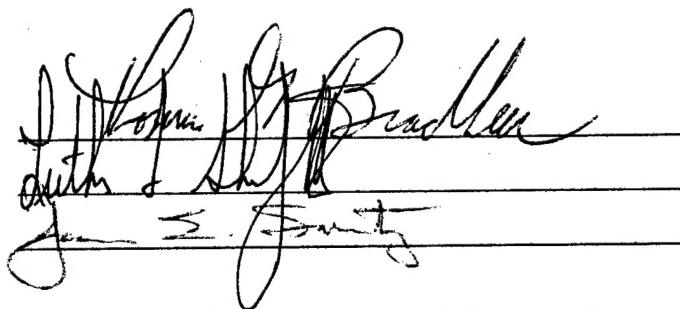
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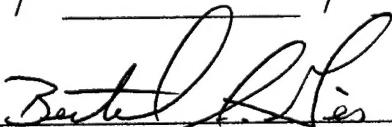
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